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Charles G. Johnston

1899–1960

Founding Editor

The man chosen to be the first editor of this Journal was Dr. Charles G. Johnston. He was a unique figure in American Surgery. No one to my knowledge fought more vigorously for those things which he believed to be in the best interests of American Surgery or fought more vigorously against those things which he thought were harmful to American Surgery. His death leaves a place that will be difficult to fill. He was one of those who helped to found this Association. He was one of those remarkable individuals who was willing to give of his life in order that the best interests of surgery might be served.

I. S. RAVDIN, M.D.

Foreword

I. S. Ravdin, M.D.

The automobile alone has killed more Americans than all the wars the United States has fought in. Add to automobile deaths those killed at home, work and in public conveyances and the present annual toll becomes nearly 100,000 deaths per year. Add the non-fatal injuries and one has over nine million civilian casualties a year, compared with one million military casualties in the four years of World War II. These losses are truly staggering.

While the prevention of injury is not primarily the responsibility of the physician, the care of the injured most emphatically is. It is my firm belief that we surgeons have been remiss in our duty to the injured patient. Except during periods of warfare, the injured patient frequently receives less expert care than almost any other type of patient.

There are many causes for this. Trauma strikes unexpectedly and is difficult to prepare for in any systematic manner. It is easier to follow an army around with mobile hospital units than to anticipate the civilian population in its peregrinations. The increasing specialization among surgeons often makes it a matter of fate whether the right injury will find the right surgeon at the right time. Ask yourself what decision you would make if you had to choose for a member of your own family between a serious injury and an equally serious surgical disease, if treatment were to be "average". Time and circumstance often prevent the injured patient from receiving the same degree of surgical skill as the diseased patient receives. A potent reason for more emphasis on the surgery of trauma! Medico-legal complications make treatment of injuries unpopular among many surgeons. However important each of the above reasons, they add up to an unpleasant situation in which we American surgeons have tended to neglect the injured patient during times of peace.

The American Association for the Surgery of Trauma has striven for better care of the injured since its founding in 1938. To further this aim it is sponsoring this new Journal of Trauma. The Association took this step after long and careful study. There were a number of strong dissenting voices: "Another surgical journal? We already have too many, and the standards of the ones we have are too low." But I am sure that there is never too much of something good which answers a specific need. The cause of the injured patient has been dissipated among a dozen journals. We do not have, in spite of our many journals, enough topnotch medical writing in this country. If the Journal of Trauma establishes and keeps the high standards I hope it will, it will tend to raise the standards of trauma articles throughout all our medical literature. And it will provide a clear picture of the whole problem of trauma and the injured patient as it appears every year in its infinite variety.

I wish this new journal the best of success. It can help raise the level of the care of the injured to that of any other surgical lesion.

THE HOUSING PROBLEM OF THE OSTEOBLAST

J. TRUETA*

Most of the numerous contributions to osteogenesis pay due attention to the role of the cells first mentioned by Goodsir (2) (1845) as "flattened, elongated and more or less turgid, belonging doubtless to the system of haversian cells which surround the vessels in their course and separate them from the cells of the canals". These cells were called normal osteoblasts by Gegenbauer (1) (1864).

At the present time there is no serious conflicting view on the function of these cells and their part in laying down the matrix of collagen fibres and—even if this is less unanimously accepted—in producing the ground substance of mucopolysaccharides on which the crystals of hydroxyapatite deposition occurs.

Most of the contemporary authors agree that the osteoblasts become the osteocytes but there is still no general agreement as to the origin of the osteoblast. Many authors believe that they arise by metaplasia of connective tissue cells, either in their embryonic form or from their mature relative, the fibroblasts. Beyond these two widely accepted views among experts the final destruction of the osteocyte in bone resorption on the one hand is even now the object of much debate. This, and the suspicion I repeatedly felt in the course of my work on osteogenesis that the vessels had a more direct responsibility in the process of bone formation than that now suspected by having an active part in the genesis of the osteoblast induced me to engage in an investigation on the subject.

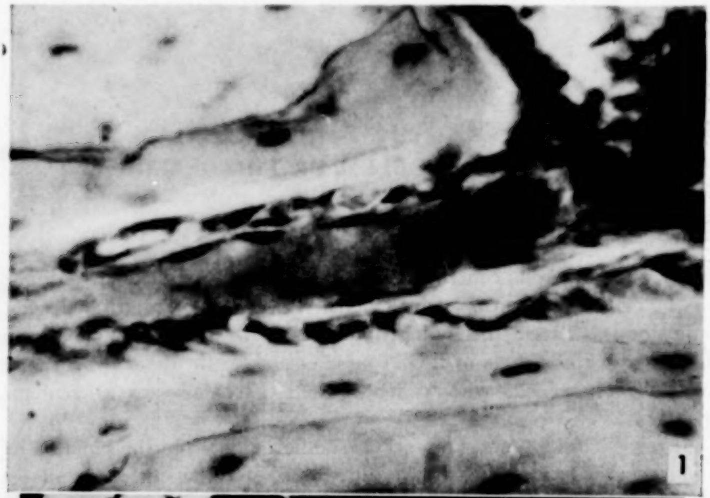
The material used was obtained both by stimulating bone removal by experimental osteoporosis and bone formation in the callus of fractures of rabbits and dogs. After two years work the results on the relationship of the osteoblast and the vascular cells were still inconclusive, not because we had not repeated evidence of intimate connection between the two systems of cells (Fig. 1) but because of our inability to obtain data from experiments which had an excessive individual variation.

We finally decided to study the laying down of osteoblasts in the area of early ossification occurring in the process of normal growth near the metaphyseal end of the growth plate, for there it is well known that bone formation takes place exactly at the same place and in a similar way by whatsoever species of material we studied.

For this work we used mainly specimens in which the vessels had been perfused by a fine suspension of barium (Micropaque) and which after preparation were examined both by the light and electron microscope. In this short paper I am giving an account of the main findings of this work.

Read before the Twentieth Annual Session of The American Association for the Surgery of Trauma, Coronado, California, October 5–7, 1960.

* Nuffield Professor of Orthopaedic Surgery, University of Oxford, England. From the Nuffield Orthopaedic Centre, Oxford.



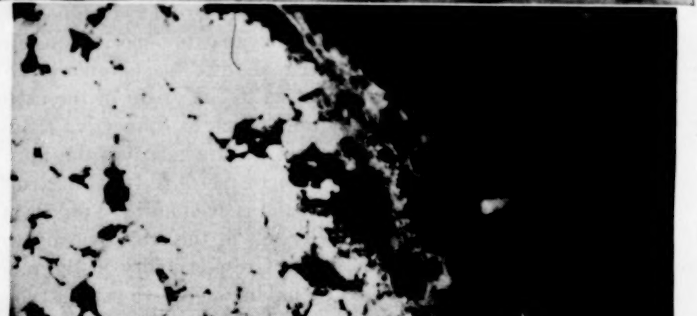
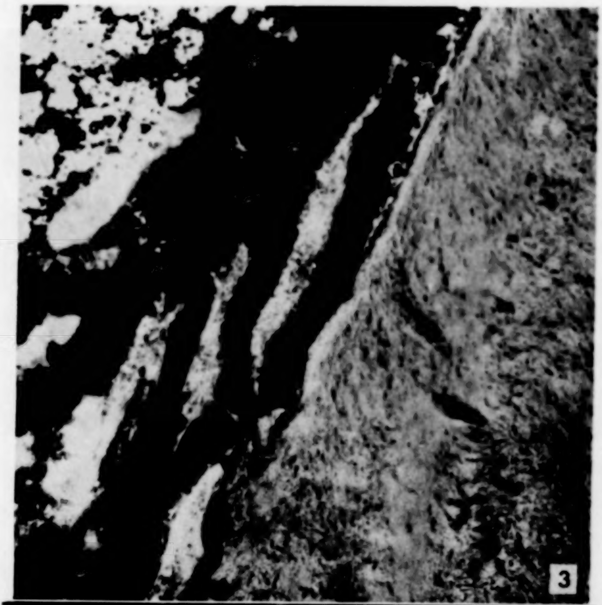


FIG. 1. Photomicrograph showing intimate relation between the vascular cells and the osteoblasts. (× 500).

FIG. 2. Cell division in the vascular endothelium. Vessel filled with injection mass to the left, cell at right center just finishing its division (× 5,000).



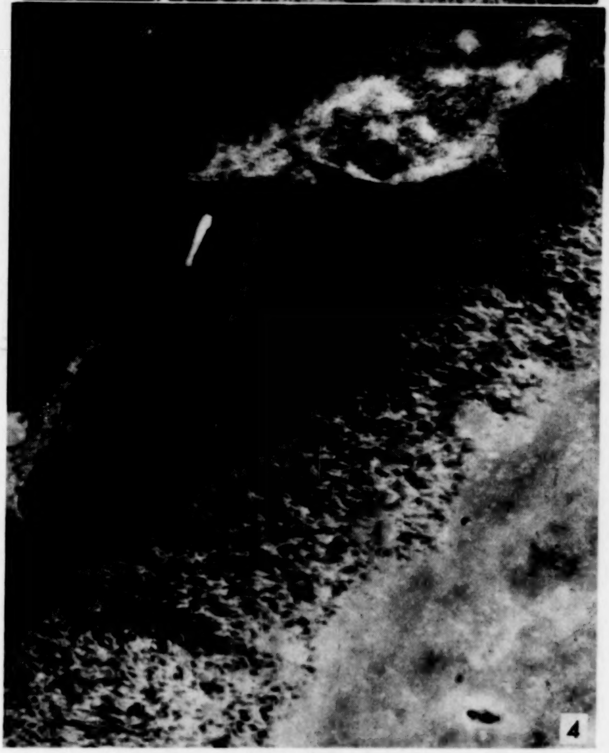
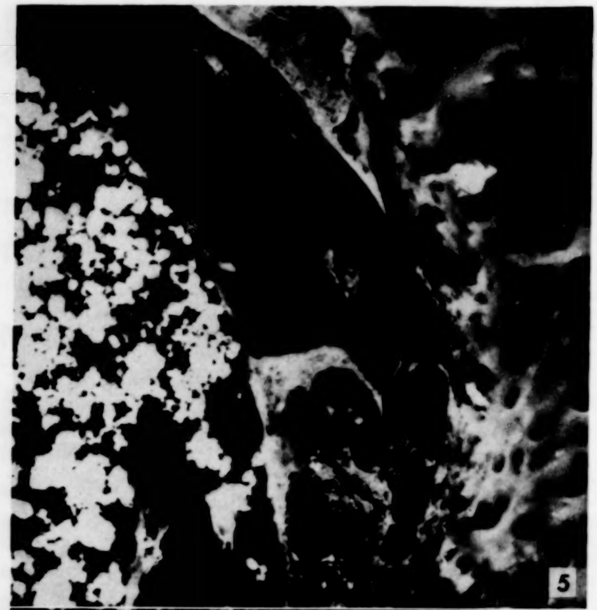


FIG. 3. Several cells of vascular origin, after division, sectioned longitudinally. The vessel is seen at the top left. The two cells on top of each other at the middle of the illustration are facing the calcified cartilage and are attached to each other by cytoplastic processes. These are evidently osteoblasts in their early appearance. (× 5,000).

FIG. 4. Osteoblasts in the process of laying down the collagen matrix. (× 10,000)



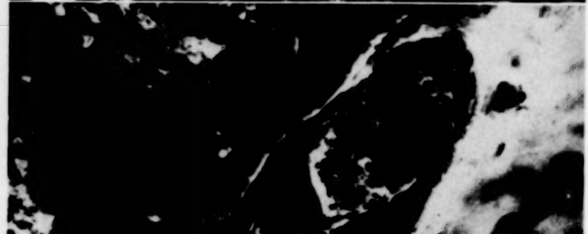
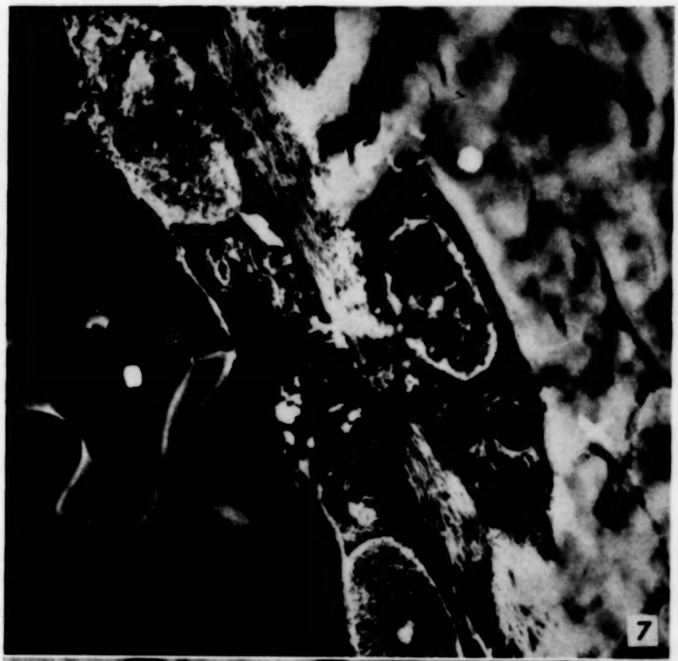


Fig. 5. Injected vessel on the right, with endothelial cells (center) closely connected to the calcified tissue on the left. (× 5,000).

Fig. 6. A large osteoblast in the process of being covered by the crystals of hydroxyapatite. (× 5,000).



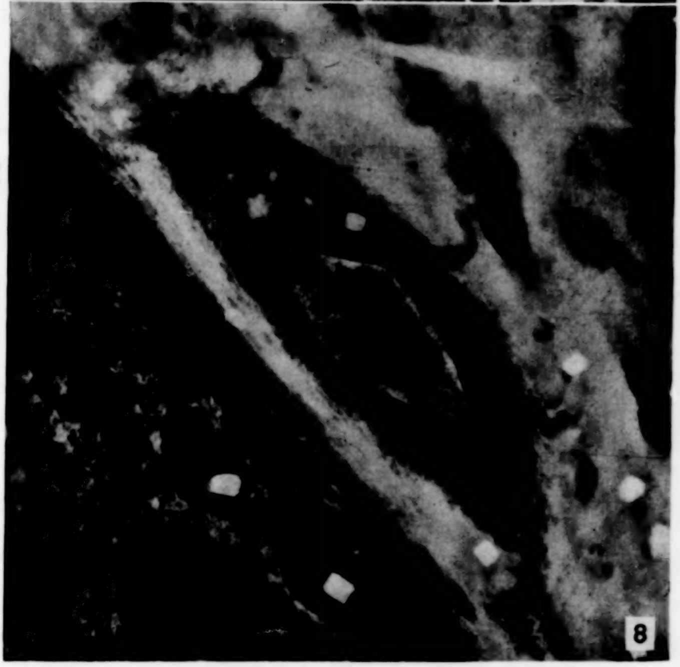
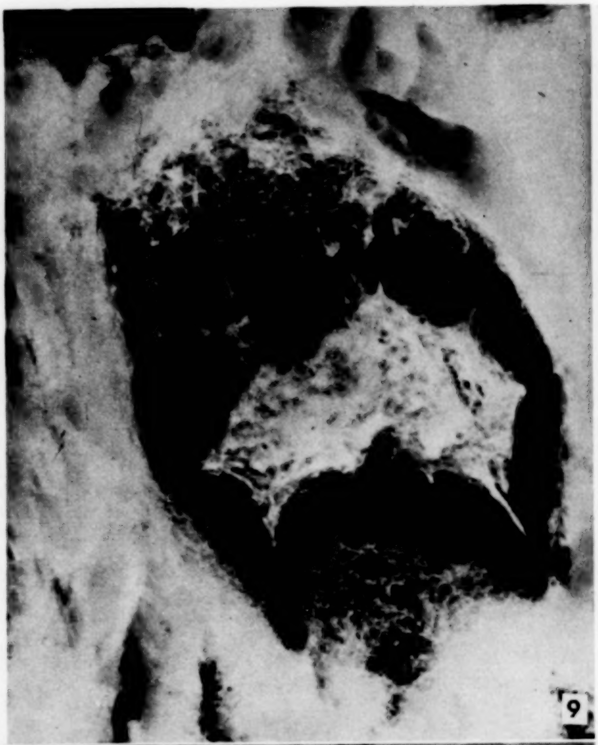


FIG. 7. A blood vessel to left of picture (note red corpuscles in lumen) with two endothelial cells, while another cell close to them is being encased by the mineral deposit. Large canaliculi are seen crossing the area of calcified tissue on the right, in several directions. (× 5,000).

FIG. 8. An early osteocyte and another cell still an osteoblast (lower left) are seen together with several canaliculi. (× 5,000).



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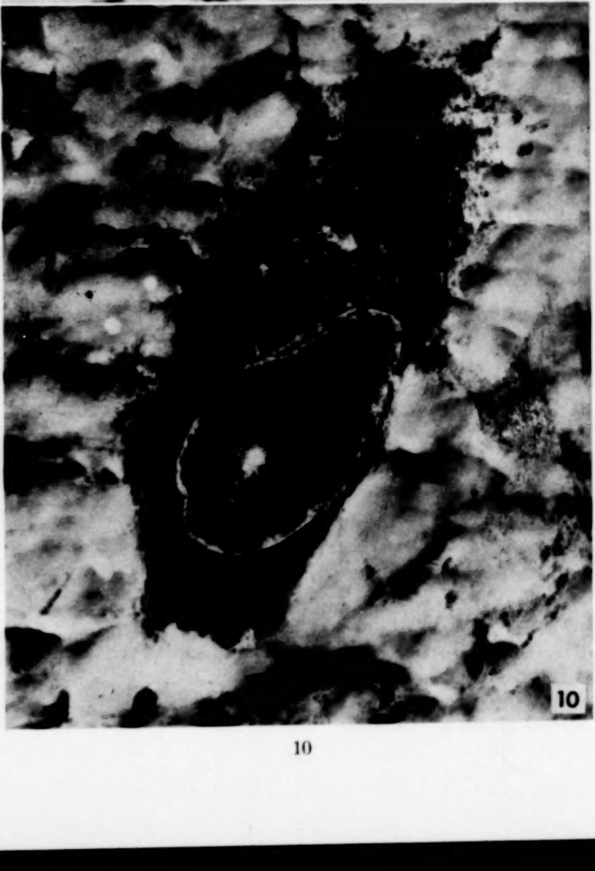

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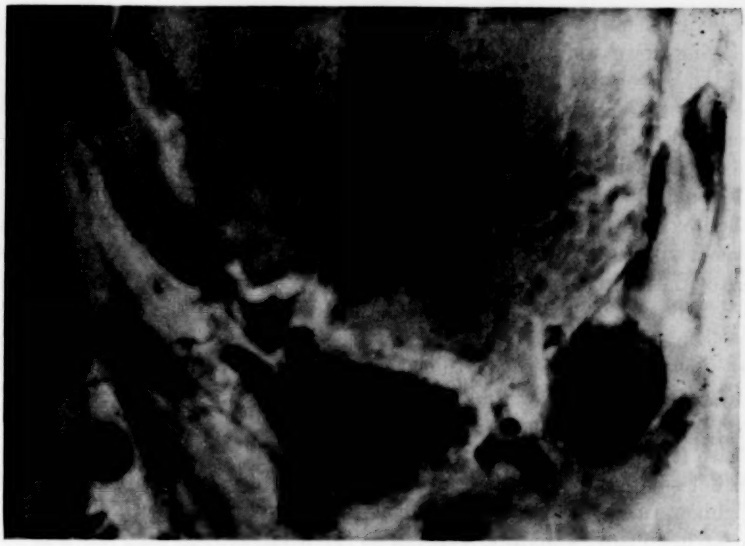

FIG. 11. An osteocyte, still connected with what appears to be an osteoclast in formation. (× 1,200).

The growth plate, as stated in previous works (3) from this Centre (1960) and other places, calcifies in its intercolumnar spaces at its metaphyseal end from the level almost of the third last cartilage capsule downwards in the growth column. The vascular loop occupies with its two long arms the centre of this calcified tube and ends just underneath the last intercapsular septum still enclosing a degenerating hypertrophic chondrocyte.

We will now focus our attention at about the place occupied by the last but one of these capsules which is penetrated by the progressing vessel.

In the illustrations which follow, the way in which a cell of the vascular endothelium (Fig. 2—transversal section) divides is shown. The vessel outlined by the reticulin wall is shown filled by the injection mass. The cell at the right of the electron microscope photograph appears just finishing its division.

Fig. 3 exhibits several of the cells of vascular origin (the vessel is seen at the top left hand corner) after division, sectioned longitudinally. The two cells on top of each other at the middle of the illustration are facing the area of calcified cartilage and may be seen attached to each other by cytoplastic processes. These are evidently osteoblasts in their early appearance. Fig. 4 shows at its top an

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FIG. 9. A fully developed osteocyte. The protoplasmic processes entering the canaliculi and attaching the cell with its neighbors are made evident by retraction of the cell during fixation. (× 7,500).

FIG. 10. A mature, well buried osteocyte, with large nucleus and numerous canaliculi through which the processes extend. (× 5,000).

already evident osteoblast and at its mid left, half of another; both in the process of laying down the collagen matrix. In the following illustration (Fig. 5) the injected vessel on the right shows two large endothelial cells very closely connected to the calcified tissue on the left. This is no longer calcified cartilage because of the presence of a large number of canaliculi which allows us to classify it as organized bone.

Fig. 6 depicts a large osteoblast in the process of being covered by the crystals of hydroxyapatite. Only the part corresponding to the vessel is still very sparcely covered with these, while in the next illustration (Fig. 7) the vessel (demonstrated here by the red corpuscles occupying its lumen in the left of the picture) appears, with two endothelial cells, while another cell close to them is well into the process of being encased by the mineral deposit. Large canaliculi appear in several directions crossing the area of calcified tissue on the left. In Fig. 8 an early osteocyte and another cell still an osteoblast (lower left) are well seen together with several canaliculi on the right.

Two fully developed osteocytes are shown in Figs. 9 and 10. In the first, the protoplasmatic processes entering the canaliculi and attaching the cells with its neighbours are made clearly evident by the retraction of the cell during fixation. In the last figure, a mature, well buried osteocyte with its large nucleus and its numerous canaliculi, through which the processes extend, is shown.

As there is no other source for the cells here illustrated in this series other than the vascular endothelium, we are forced to conclude that, at least in this most important area of osteogenesis, the bone forming cell we call the osteoblast cannot come from other than the vascular cell. This is an observation based on examination of a very large mass of material taken from different species. The endothelial cell in the presence of the calcified cartilage enters into division and its descendants—sometimes at the first generation—acquire the characteristics of the osteoblasts with large nuclei, long processes and the ability to lay down the matrix on which the crystals are fixed. It is clear then, that the osteoblast was an endothelial cell on its way to become housed into the bone. From then on, provided that the canaliculi remain opened and the blood carries its due proportion of the necessary elements the osteocyte will remain alive for a long time, at least until bone removal, by carrying away the mineral part of the bone, will leave the cell again unprotected. Perhaps then, going with others will cause the osteoclasts of whose origin we as yet know nothing. Fig. 11 may contribute to suggest this possibility for there an osetocyte is seen still connected with what appears to be an osteoclast in formation.

REFERENCES

1. Gegenbauer, C. Über die Bildung des Knochengewebes. Jen. Zeitschr. f. Naturw. **1:** 343–369, 1864.
2. Goldsir, J. and Goodsir, H. D. S. Anatomical and Pathological Observations. M. Macphail, Edinburgh, 1845.
3. Trueta, J. and Amato, V. P. The Vascular Contribution to Osteogenesis III. Changes in the Growth Cartilage Caused by Experimentally Induced Ischaemia. J. Bone & Joint Surg., **42-B:** 571–587, 1960.

TRAUMA, SURGERY, AND CIRCULATION OF THE TALUS—WHAT ARE THE RISKS OF AVASCULAR NECROSIS?

ROBERT L. LARSON, M.D., C. ROGER SULLIVAN, M.D., AND JOSEPH M. JANES, M.D.

From the Mayo Clinic and Mayo Foundation,[1] *Rochester, Minnesota*

The frequent occurrence of avascular necrosis of the talus following injury to this bone has given rise to the concept that the blood supply to the bone is poor or inadequate. Sneed (9) stated in 1925 that there was no main nutrient artery to this bone but that blood was supplied by numerous small vessels. He expressed the opinion that these vessels could not be stretched to the degree necessary for dislocation of the talus without rupture.

Watson-Jones (11) described a more generous blood supply to the talus through all of its ligamentous attachments. He indicated that fractures through the neck of the talus with rupture of all vessels entering from the sinus tarsi would not cause avascular necrosis since there was adequate blood from the dorsal and posterior vessels to supply both fragments of the bone, but that posterior dislocation of the body would cause complete disruption of its blood supply and avascular necrosis would result.

McKeever (7), writing in 1943, stated that Watson-Jones attributed too ample a circulation to the talus and indicated that the entire vascular supply was derived from branches of the anterior tibial artery carried in the superior taloscaphoid ligament to the neck of the talus. McKeever's views became widely quoted and accepted.

RECENT STUDIES ON CIRCULATION OF THE TALUS

Recent general interest in the study of extra-osseous and intra-osseous circulation of various bones of the body has stimulated the development of better injection technics for demonstrating the blood supply of bone. These technics have been especially useful in studying the circulation of the talus where such a wide divergence of opinion has existed. Work by Wildenauer (12) in Germany; by Lauro and Purpura (5) and Frignani and Vitolli (2) in Italy; and by Haliburton, Sullivan, Kelly and Peterson (3) in this country, has served to clarify the vascular anatomy of the talus.

The technic used by Haliburton and associates at the Mayo Clinic involved perfusion of 14 extremities amputated for nonvascular diseases. A solution of saline containing sodium nitrite was injected into the popliteal artery. This was followed by the injection of a suspension of India ink and gelatin. The extra-osseous vessels were then dissected and the extra-osseous circulation was demon-

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Read before the Nineteenth Annual Session of The American Association for the Surgery of Trauma, Bretton Woods, New Hampshire, September 24–26, 1959.

[1] The Mayo Foundation is a part of the Graduate School of the University of Minnesota.

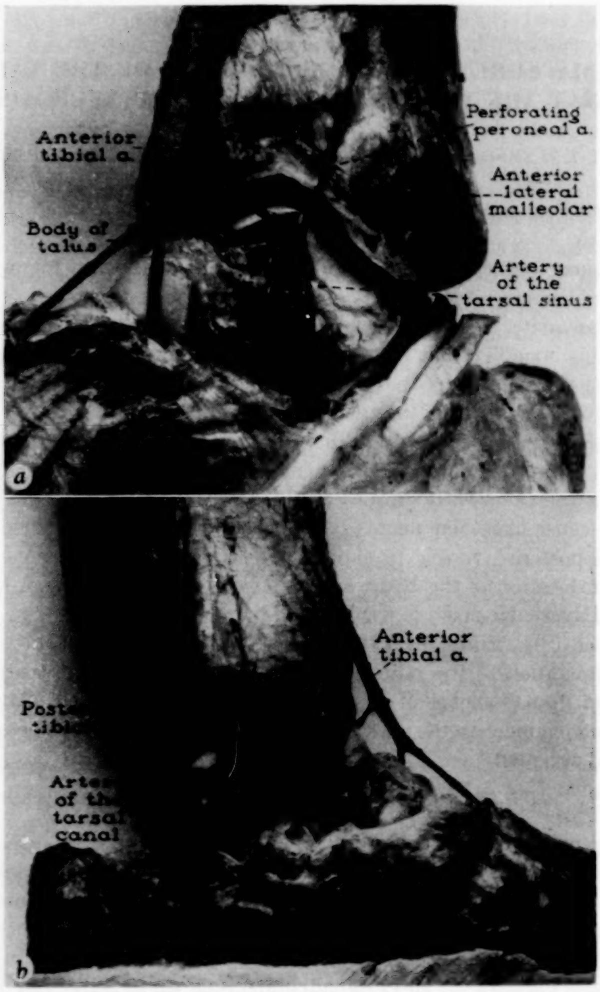
Anterior tibial a.
Perforating peroneal a.
Anterior lateral malleolar
Body of talus
Artery of the tarsal sinus
a
Anterior tibial a.
Poste
tibi
Arte
of th
tarsal
canal
b

FIG. 1. Dissection of lateral and medial sides of the ankle showing the vessels which had been injected with India-ink and gelatin suspension. *a.* Lateral view showing the artery of the tarsal sinus arising from the anterior lateral malleolar artery. *b.* Medial side showing the vessels of the tarsal canal arising from the posterior tibial artery.

strated. The tali were sectioned in various planes and cleared by means of the Spalteholtz technic. By this method the intra-osseous circulation was clearly visualized and a detailed study was permitted.

Contrary to the older concepts of the paucity of the blood supply to the talus, the recent work indicates an adequate blood supply.

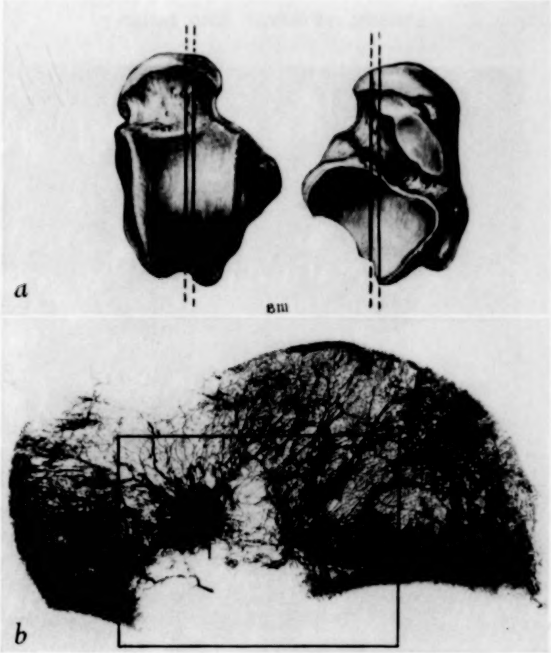

FIG. 2. *a*. Superior and inferior views of right talus showing the site of origin of the sagittal section shown in *b*. *b*. Sagittal section through talus at site indicated by *a* after injecting vessels with an India-ink and gelatin suspension and clearing by the Spalteholz technic. Note the major supply of blood entering the inferior portions of the body in the region of the junction of tarsal sinus and tarsal canal. Note also the vessels entering inferiorly and supplying the head of the talus.

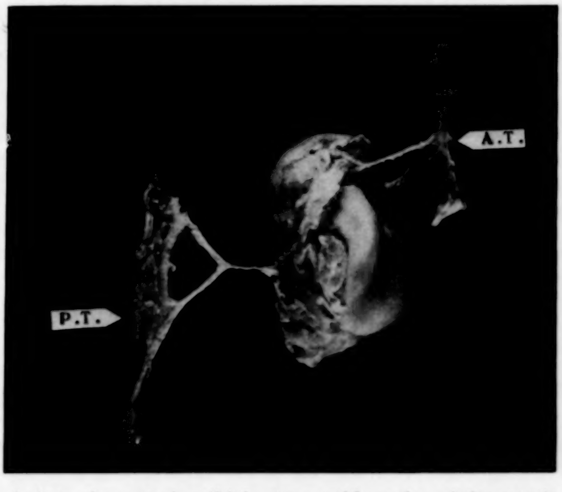

FIG. 3. Vessels from the posterior tibial artery and branches of the anterior tibial artery which anastomose inferiorly to the talus at the junction of the tarsal canal and tarsal sinus.

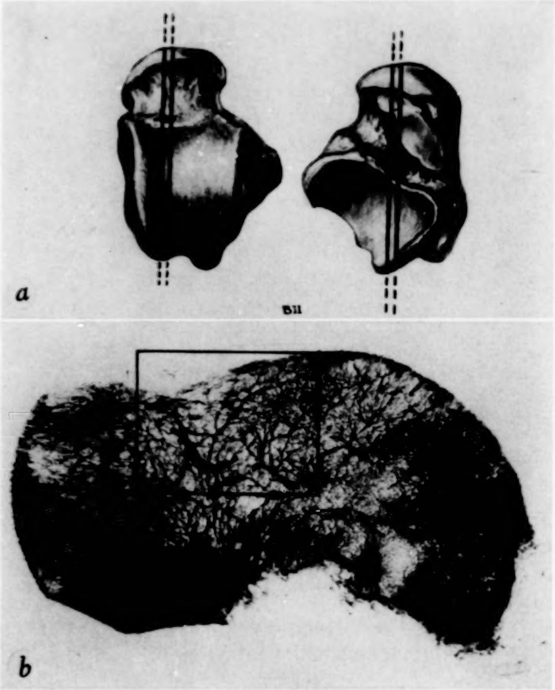

Fig. 4. *a*. Superior and anterior views of right talus showing the site of origin of the sagittal section shown in *b*. *b*. Sagittal section through talus injected with India-ink and gelatin suspension and cleared by the Spalteholz technic. Note the intra-osseous supply to the head from vessels entering from the superior surface of the neck.

TABLE 1

Avascular Necrosis After Arthrodesis

Procedure		Avascular Necrosis	
Type	Total number performed	Number of cases	Per cent
Triple arthrodesis and Grice arthrodesis	234	14	6.0
Lambrinudi arthrodesis	40	3	7.5
Total	274	17	6.2

The extra-osseous circulation to the talus is via the three main arteries of the lower portion of the leg through a periosteal vascular network, which covers all of the cartilage-free surfaces, and via two discrete vessels: the artery of the tarsal sinus arising variably from one of the dorsolateral arteries (fig. 1*a*) and the artery of the tarsal canal arising from the posterior tibial artery (fig. 1*b*).

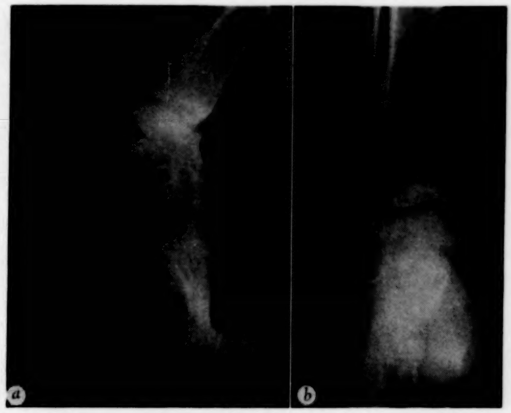

FIG. 5. Roentgenogram made 10 months after triple arthrodesis. Avascular necrosis of the body of the talus extending into the neck and head. *a*. Lateral view. *b*. Anteroposterior view.

Wildenauer stated that the vessels of the tarsal sinus and the tarsal canal together with the medial periosteal network are the most important source of blood to the talus.

The major part of the blood supply to the body of the talus enters anteroinferiorly through the neck of the talus (fig. 2). Blood is brought to this part of the bone by a "sling" anastomosis of the artery of the tarsal sinus approaching from the anterolateral aspect and the artery of the tarsal canal approaching from the posteromedial aspect (fig. 3). The head is supplied by vessels entering from the superior surface of the neck (fig. 4) and inferolateral aspect of the neck which faces the tarsal sinus (fig. 2).

As a result of these studies on the circulation of the talus, we were led to the logical question, "Why does avascular necrosis not develop more frequently after surgical procedures in the region of the sinus tarsi?" Thus the purpose of this study was to determine the incidence of avascular necrosis following triple arthrodesis, Lambrinudi arthrodesis, and the Grice bone-block procedure, since all three operations interrupt the arteries of the tarsal canal and the tarsal sinus.

MATERIALS AND METHODS

The material on which this study was based included the roentgenograms of 242 patients who had undergone 274 major surgical procedures on the talus during the 10-year period from January 1, 1948, through December 31, 1957. Also included were the roentgenograms of 19 fracture dislocations of the talus. The longest roentgenologic follow-up was 12 years and the shortest was 2 months. An attempt was made to correlate the type of surgical procedure or fracture with the appearance of avascular necrosis.

RESULTS

Of the 274 surgical procedures that were performed 234 were either triple arthrodesis or Grice operations and 40 were Lambrinudi arthrodeses. Avascular necrosis of the talus developed after 17 (6.2 per cent) of the 274 procedures (table 1) (fig. 5). The body of the bone was involved in every instance and necrosis of the neck of the talus also developed in five cases. In two cases the entire talus became necrotic. One patient had undergone complete removal of the body of the talus. There was no evidence of necrosis in the remaining neck and head.

Roentgenograms of 18 fractures of the talus and one anterior dislocation without fracture were reviewed. Evidence of avascular necrosis appeared in 11

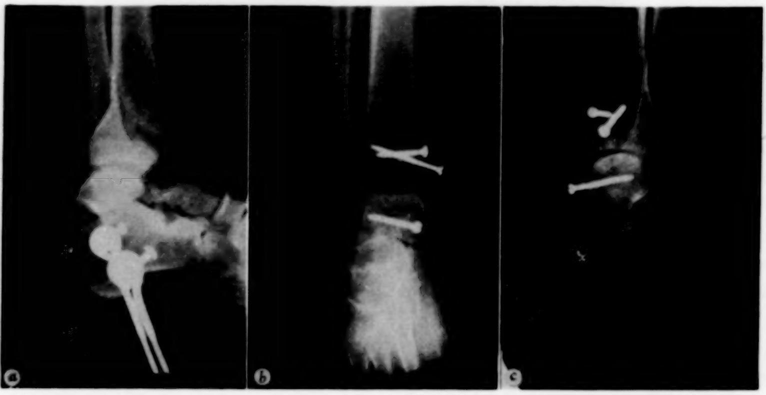

FIG. 6. *a*. Fracture dislocation of the talus. *b* and *c*. Anteroposterior and lateral views taken 8½ months after injury. Note avascular necrosis of the body of the talus. Later this portion was revascularized.

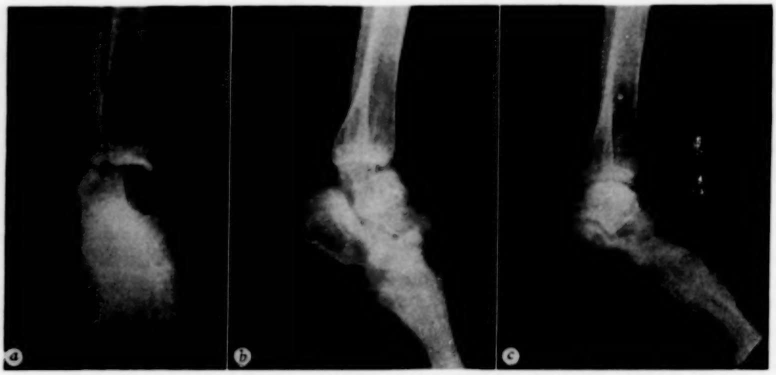

FIG. 7. *a* and *b*. Anteroposterior and lateral views showing anterolateral dislocation of the talus. There is no apparent fracture of the talus. These roentgenograms were made 3 days after the original injury. *c*. Roentgenogram made 2 months later showing avascular necrosis of the body of the talus.

TABLE 2

Avascular Necrosis After Trauma to Talus

Type of trauma	Cases		
	Total	Avascular necrosis	
		Number	Per cent
Dislocation	1	1	100
Fractures	18	10	56
Location:			
Neck only	7	4	57
Body only	6	5	83
Head only	1	0	0
Neck and body	4	1	25
Associated with dislocation on initial roentgenogram	5	3	60

roentgenograms including the case of dislocation (figs. 6 and 7). The body of the talus was involved in every instance and one roentgenogram revealed some involvement of the neck. No case of necrosis of the head was found (table 2).

The incidence of avascular necrosis following injury to the talus cannot be surmised from this series since the cases were not consecutive. The series merely represents a study of roentgenograms which were available to us, many other roentgenograms having been discarded because of lack of storage space.

Marek and Schein (6) reported in 1945 on avascular necrosis following arthrodesis. They reported two cases of avascular necrosis in one series of 17 cases and three cases of avascular necrosis of the talus in another series of 44 cases. They stated that in two of these five cases avascular necrosis developed after secondary operations. All secondary operations involved extensive resection of the head and neck. In one case in the series reported herein, avascular necrosis developed after a secondary procedure. Of the entire 274 procedures arthrodesis was performed in only two for the second time.

COMMENT

It is difficult to predict with any degree of accuracy whether or not the talus will undergo avascular necrosis after fracture. The original roentgenogram after injury does not indicate the position of the fragments at the moment of impact. In our opinion, therefore, accurate evaluation of damage to the blood supply is extremely difficult if not impossible.

Evaluation of the incidence of avascular necrosis of the talus following arthrodesis is more enlightening. The chief source of the blood supply to the talus comes from the subtalar region via the arteries of the tarsal canal and sinus and the posterior tibial vessels. Avascular necrosis does not develop with any regularity following arthrodesis even though the source of the blood supply is disrupted in these procedures. It is obvious, therefore, that in most patients the

TABLE 3

Avascular Necrosis After Fracture and Dislocation Reported in Literature

Author	Year	Total	Cases	
			With avascular necrosis	
			Number	Per cent
McKeever	1943	17	12	71
Schrock	1952	—	—	50
Coltart	1952	166	34	20
		7*	5*	71
		38†	12†	32
		31‡	14‡	45
Watson-Jones	1955†	—	—	50
Sullivan and Jackson	1958	47	7	15

* Fracture of body with subtalar dislocation.
† Fracture of neck with subtalar dislocation.
‡ Fracture of neck with dislocation of body.

blood supply from the periosteal vascular network is adequate to maintain viability.

The seriousness of trauma to the talus can be appreciated when it is realized that the talus is without muscular origin or insertion (4), that three fifths of its surface is articular cartilage, that the outstretched neck is quite vulnerable to injury, and that its blood supply often is disrupted internally due to comminution as well as externally by rupture of ligaments.

The incidence of avascular necrosis after fracture and dislocation of the talus reported in the literature varies from 15 to 71 per cent (table 3). This wide divergence attests to the difficulty in predicting avascular necrosis after injury. The incidence of avascular necrosis after arthrodesis of the talus is relatively constant. Marek and Schein reported an incidence of 8 per cent. Our series showed an incidence of 6.2 per cent.

Two circumstances possibly contribute to the decreased incidence of avascular necrosis subsequent to arthrodesis as compared to that after injury to the talus: (1) there is no disruption of the intra-osseous blood supply during operation, and (2) during arthrodesis the cancellous bone of the talus is exposed and approximated to adjacent bones. This may allow easier vascularization of the talus after operation. The marked difference between the high incidence of avascular necrosis after talar injury and the relatively low incidence after arthrodesis may be ascribed to the greater damage to the intra-osseous blood supply associated with the former.

The immeasurability of initial trauma is the variable factor which accounts for the difference in incidence of avascular necrosis. The die is cast at the time of fracture as to whether or not avascular necrosis will develop.

SUMMARY AND CONCLUSIONS

Recent studies have shown the vascular supply to the talus to be plentiful. The older idea of a single blood supply from the branches of the anterior tibial artery is no longer tenable. Rather there are two discrete vessels to the talus and a periosteal vascular network supplied by three main arteries which vascularize this bone.

Avascular necrosis occurred in 6.2 per cent of tali after arthrodesis in our series of 274 procedures.

In all probability the low incidence of avascular necrosis after surgical intervention is due to its adequate blood supply from the periosteal vascular network. The higher incidence of necrosis subsequent to trauma is considered to be due to the greater disruption of intra-osseous vessels caused by compression and comminution at the moment of impact.

ACKNOWLEDGMENT

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REFERENCES

1. Coltart, W. D. Aviator's astragalus. J. Bone & Joint Surg., **34-B:** 545–566, 1952.
2. Frignani, R. and Vitolli, G. Sulla circolazione arteriosa dell 'astragalo. Clin. Bologna, **16:** 315–327, 1956.
3. Haliburton, R. A., Sullivan, C. R., Kelly, P. J. and Peterson, F. A. The extra-osseous and intra-osseous blood supply of the talus. J. Bone & Joint Surg., **40-A:** 1115–1120, 1958.
4. Kelikian, H. *The ankle: dynamic and circulatory relations of the ankle.* In: American Academy of Orthopaedic Surgeons: Instructional Course Lectures, vol. 9, pp. 347–360, J. W. Edwards Co., Ann Arbor, 1952.
5. Lauro, A. and Purpura, F. La trabecolatura ossea e l'irrorazione sanguigna nell 'astragalo e nel calcagno. Minerva chir., **11:** 663–667, 1956.
6. Marek, F. M. and Schein, A. J. Aseptic necrosis of the astragalus following arthrodesing procedures of the tarsus. J. Bone & Joint Surg., **27:** 587–594, 1945.
7. McKeever, F. M. Fracture of the neck of the astragalus. Arch. Surg., **46:** 720–735, 1943.
8. Schrock, R. D. *Fractures of the foot: fractures and dislocations of the astragalus.* In: American Academy of Orthopaedic Surgeons: Instructional Course Lectures, vol. 9, pp. 361–368, J. W. Edwards Co., Ann Arbor, 1952.
9. Sneed, W. L. The astragalus: a case of dislocation, excision, and replacement: an attempt to demonstrate the circulation in this bone. J. Bone & Joint Surg., **7:** 384–399, 1925.
10. Sullivan, C. R. and Jackson, S. C. Fracture dislocations of the astragalus in children. Acta orthop. scandinav., **27:** 302–309, 1958.
11. Watson-Jones, R. *Fractures and Joint Injuries*, vol. 2, pp. 445–1073, Williams & Wilkins Co., Baltimore, 1955.
12. Wildenauer, E. Die Blutversorgung des Talus. Ztschr. Anat., **115:** 32–36, 1950.

SEPTICEMIA IN BURN INJURY

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Invasive bacterial infection continues to be one of the major unsolved problems in the treatment of patients who have sustained severe burns. In 1954, Liedberg (7), reporting from this Unit, observed that of 35 burned patients who died at this installation between 1950 and 1953, death in 12 was due to septicemia. The purpose of this report is to review the clinical and laboratory findings, as well as the mortality data, in burned patients treated between 1954 and 1959 and to emphasize the rising incidence and irreversibility of invasive *Pseudomonas* infection associated with burn injury.

The clinical management of the severe burn did not vary appreciably during the six years covered by this survey, except for a gradual abandonment of the use of occlusive dressings in favor of the exposure method. Antibiotics were administered as indicated by clinical findings and microorganism sensitivity, and newly discovered antimicrobial agents were employed as they became available. Blood cultures were drawn aseptically after appropriate skin preparation, and organisms were cultured and isolated using accepted bacteriological methods. Numerous negative cultures were obtained, and false positive reports are thought to be minimal. All patients considered to have had septicemia in this report had one or more ante mortem positive blood cultures.

Five hundred and ninety-six (596) patients with burns were treated at the United States Army Surgical Research Unit between 1954 and 1959. Table 1 records the annual incidence of death and the per cent of these deaths with associated septicemia. The yearly variation in the incidence of death (14.68 per cent to 26.44 per cent) and the proportion of deaths with septicemia (47.83 per cent to 75.00 per cent) in these patients shows no significant trend and probably results from differences in the extent and depth of burn, areas involved, magnitude of associated injuries, patient age, and presence of pre-existing disease. Of great interest is the fact that 77 of 123 deaths (62.60 per cent) were associated with septicemia. Invasive infection, therefore, was present in almost two-thirds of the burned patients who died and appears to be the greatest challenge to survival in burn injury.

Table 2 records the annual incidence of septicemia and the per cent of patients

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Read before the Twentieth Annual Session of The American Association for the Surgery of Trauma, Coronado, California, October 5-7, 1960.

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TABLE 1

Mortality and Septicemia in Burn Injury

1954–1959

Year	Total Patients	Deaths		Septicemia Deaths	
		No.	% of patients	No.	$\frac{\text{Deaths with septicemia}}{\text{Total deaths}} \times 100$
1954	109	16	14.68	12	75.00
1955	111	21	18.92	15	71.43
1956	95	22	23.16	11	50.00
1957	84	17	20.24	12	70.59
1958	87	23	26.44	11	47.83
1959	110	24	21.82	16	66.67
Total............	596	123	20.64	77	62.60

TABLE 2

Incidence of Septicemia and Survival in Burn Injury

1954–1959

Year	Total Patients	Septicemia		Septicemia Survivors	
		No.	% of patients	No.	$\frac{\text{Survivors of septicemia}}{\text{Total septicemias}} \times 100$
1954	109	13	11.93	1	7.69
1955	111	19	17.12	4	21.05
1956	95	13	13.68	2	15.38
1957	84	16	19.05	4	25.00
1958	87	13	14.94	2	15.38
1959	110	20	18.18	4	20.00
Total...........	596	94	15.77	17	18.08

who survived blood stream invasion in each year. Seventeen (18.08 per cent) of 94 burned patients with septicemia survived. Only one of five patients, therefore, survived severe burn injury and septicemia.

Before analyzing the septicemia data in any greater detail, it is of interest to examine the reports of cultures from burn wound surfaces. Table 3 reflects the incidence of the more commonly occurring pathogens in cultures of burn wounds between 1954 and 1959. Since the sampling was not controlled in relation to the postburn day and number of cultures per patient, the data are weighted by the bacterial flora of patients who survived longer. The increasing frequency of isolation of *Pseudomonas* organisms, of greater magnitude than the increase seen in other organisms, is apparent. By 1956, *Pseudomonas* surpassed *Staphylococcus* in frequency of occurrence and has since been the most commonly found pathogen in burn wound cultures. The decrease in the incidence of all organisms

TABLE 3

Incidence of Organisms Isolated from Cultures of Burn Wound Surfaces

1954–1959

Year	Total No. Cultures	% Staph. aureus	% Pseudomonas	% Proteus	% B.H. Streptococcus
1954	1420	56.76	45.56	22.89	14.44
1955	1277	61.79	58.10	46.99	18.56
1956	1306	46.25	65.16	37.37	15.24
1957	1373	66.86	79.02	30.88	19.37
1958	1791	41.49	53.82	13.68	6.88
1959	2217	33.60	38.61	16.42	6.18

TABLE 4

Causative Organisms in Septicemia Deaths in Burned Patients

1954–1959

Organism	Year						Total
	1954	1955	1956	1957	1958	1959	
Pure Infections							
Staph. aureus	3	4	3	3	2	2	17
Ps. aeruginosa	1	3	4	5	7	7	27
Aerobacter-Klebsiella	—	1	—	—	—	1	2
Paracolobactrum	1	—	2	—	—	—	3
Proteus vulgaris	1	—	—	1	—	—	2
Serratia marcescens	—	—	—	—	1	—	1
E. coli	—	—	—	—	—	1	1
Candida albicans	—	—	—	—	1	—	1
Subtotal	6	8	9	9	11	11	54
Mixed Infections							
Staph. aureus, Pseudomonas	2	3	2	1	—	2	10
Staph. aureus, Proteus vulgaris	1	2	—	—	—	1	4
Staph. aureus, Paracolobactrum	—	—	—	1	—	—	1
Staph. aureus, Yeast	1	—	—	—	—	—	1
Staph. aureus, Proteus vulgaris, Pseudomonas	1	1	—	—	—	—	2
Staph. aureus, Pseudomonas, Paracolobactrum	1	—	—	1	—	—	2
Streptococcus, Pseudomonas, Proteus vulgaris	—	—	—	—	—	1	1
Pseudomonas, Proteus vulgaris	—	1	—	—	—	—	1
Aerobacter, B. subtilis	—	—	—	—	—	1	1
Subtotal	6	7	2	3	0	5	23
Total	12	15	11	12	11	16	77

in 1958 and 1959 is striking. In March of 1958 the burned patients were moved to a ward which had been vacant during the previous year, and rigid disciplines to prevent cross-contamination were instituted.

Table 4 tabulates the deaths associated with septicemia by causative organism and year. Fifty-four of the 77 cases (70.13 per cent) showed pure culture (one organism) septicemia, while mixed cultures (multiple organisms) were present in 23 (29.87 per cent). In the 54 cases of pure culture septicemia, 17 (31.48 per cent) had staphylococcal invasion, and 27 (50.00 per cent) had *Pseudomonas* septicemia, incriminating these two organisms in 81 per cent of these patients. In the deaths with septicemia involving multiple organisms, 22 of the 23 cases (95.65 per cent) were due to *Staphylococcus aureus* and/or *Pseudomonas aeruginosa*. Pure and mixed blood stream invasion by one or both of these organisms was present, therefore, in 66 of the 77 patients (85.71 per cent) whose burn injury was complicated by septicemia and death.

There were 17 survivors of severe burns with septicemia during this study period. Table 5 lists the organisms cultured from these patients and reports the total for each year of observation. Seven patients survived *Staphylococcus aureus* septicemia (pure culture), while 6 survived septicemia due to *Staphylococcus*

TABLE 5

Causative Organisms in Survivors of Septicemia

1954–1959

Organism	Year						Total
	1954	1955	1956	1957	1958	1959	
Pure Infections							
Staph. aureus	1	2	1	1	—	2	7
Micrococcus species	—	—	—	1	1	—	2
E. coli	—	—	—	—	1	—	1
Subtotal	1	2	1	2	2	2	10
Mixed Infections							
Staph. aureus, Micrococcus species	—	1	—	—	—	—	1
Staph. aureus, Aerobacter	—	1	—	—	—	—	1
Staph. aureus,* Ps. aeruginosa	—	—	—	—	—	1	1
Staph. aureus, Streptococcus	—	—	—	1	—	—	1
Staph. aureus, Proteus	—	—	1	—	—	—	1
Staph. aureus, Micrococcus species, Aerobacter	—	—	—	1	—	—	1
Aerobacter, Paracolobactrum, Serratia marcescens	—	—	—	—	—	1	1
Subtotal	0	2	1	2	0	2	7
Total	1	4	2	4	2	4	17

* Reported, treated and cured prior to transfer to the Surgical Research Unit.

TABLE 6

Incidence of Staphylococcus aureus and Pseudomonas aeruginosa in Deaths with Septicemia
1954–1959

Year	Total No. Septicemia Deaths	Staphylococcus aureus		Pseudomonas aeruginosa	
		No.	%	No.	%
1954	12	9	75.00	5	41.67
1955	15	10	66.67	8	53.33
1956	11	5	45.45	6	54.54
1957	12	6	50.00	7	58.33
1958	11	2	18.18	7	63.64
1959	16	5	31.25	10	62.50
Total	77	37	48.05	43	55.84

aureus and other bacteria (mixed culture). Four patients survived invasion by *Micrococcus* species and 3 *Aerobacter* species, while there was one survivor each of *E. coli* species, *Streptococcus* species, *Proteus* species, *Paracolobactrum* species, and *Serratia marcescens*. There were no survivors of *Pseudomonas* septicemia treated at this installation, even though Polymyxin B and colistin sulfate, the most effective antibiotics against this organism, were administered soon after the diagnosis was established. These data indicate that survival has occurred in septicemias due to any of the pathogens commonly encountered in burned patients except *Pseudomonas aeruginosa*.

Table 6 records the incidence of *Staphylococcus aureus* and *Pseudomonas aeruginosa* in blood cultures drawn from 77 burned patients who died with septicemia. *Staphylococcus* was demonstrated in 37 cases (48.05 per cent), and *Pseudomonas* in 43 (55.84 per cent). The gradual fall in staphylococcal incidence from 75 per cent in 1954 to 31 per cent in 1959 and the gradual rise in *Pseudomonas* from 42 per cent to 63 per cent in the past six years are apparent.

DISCUSSION

The precise role played by infection in the death of the severely burned patient remains obscure. Although this and previous reports (7, 8) document a high incidence of septicemia in these patients and imply that septicemia is the cause of death, it may be hypothesized that bacterial invasion is an agonal phenomenon following host deterioration. The fact that certain patients do survive septicemia as a complication of burns suggests that bacterial invasion occurs before deterioration has progressed to irreversibility. This leads us to believe that death with septicemia is truly death due to septicemia. We do not believe that elimination of all pathogens from the environment and the wounds of the burned patients would result in a zero mortality, but we might expect a substantial reduction if this could be accomplished.

The data presented clearly suggest an increase in the clinical importance of *Pseudomonas* septicemia and a fall in the importance of staphylococcal invasion between 1954 and 1959. Although the former is alarming and the latter gratifying, both may represent normal cycles of propagation of the species, and a return to the previous ratios may be forthcoming. If the trend, however, is real, invasion by *Staphylococcus aureus*, which has been 74 per cent fatal, is being replaced by *Pseudomonas* invasion, which has been lethal in all patients. The decline of *Staphylococcus aureus* in recent years may have been influenced by the use of more effective antibiotics. The cause for the increased clinical importance of *Pseudomonas aeruginosa* is not readily apparent. The liberal use of broad spectrum antibiotics and penicillin which destroy sensitive bacteria and allow resistant strains to flourish (2, 3, 5, 8, 14) must be considered, since all of the patients included in this report had received early antibiotic therapy.

Blood stream invasion in the severe burn is usually thought to be heralded by marked hyperpyrexia, tachycardia, paralytic ileus, severe disorientation, leukocytosis, and a gradual deterioration of granulation tissue followed by hypotension, oliguria, and death. Recent observations suggest that these findings typify invasion by the gram-positive bacteria but that burned patients with septicemia due to gram-negative organisms usually, although not always, show hypothermia, paralytic ileus, leukopenia and mental alertness, become suddenly hypotensive and anuric, and die. Table 7 tabulates these contrasting findings of septicemia. When the invading organism is *Pseudomonas aeruginosa*, multiple small areas of focal necrosis of granulation tissue are frequently the earliest sign (Fig. 1). Blood cultures are usually positive at this time. Even though large doses of Polymyxin B and/or colistin sulfate may cause subsequent blood cultures to be sterile, the clinical course and rapid demise of the patient are not altered. The patient usually remains mentally clear and often has marked hypothermia and leukopenia. Sudden profound hypotension which responds for several hours to increasing doses of vasopressor substance occurs in 12 to 48 hours. Administration of large doses of cortisone during the last 48 hours has not proved beneficial.

Microscopic examination of these areas of focal necrosis shows proliferation of gram-negative bacilli around small blood vessels, as described by Fraenkel (4). In other sections, the vessel wall is invaded and partially destroyed. Masses of gram-negative bacilli outline the adventitia and the muscularis (10).

TABLE 7

Signs of Septicemia in Burned Patients

Clinical Signs	Gram-positive Organisms	Gram-negative Organisms
Granulations	General dissolution	Focal hemorrhagic necrosis
Course	Insidious, 2–6 days	Rapid, 12–36 hrs.
Ileus	Severe	Severe
Disorientation	Severe	Mild or absent
Temperature	Hyperpyrexia	Hypothermia
Leukopenia	Absent	Marked
Hypotension	Insidious, followed by oliguria	Sudden with anuria

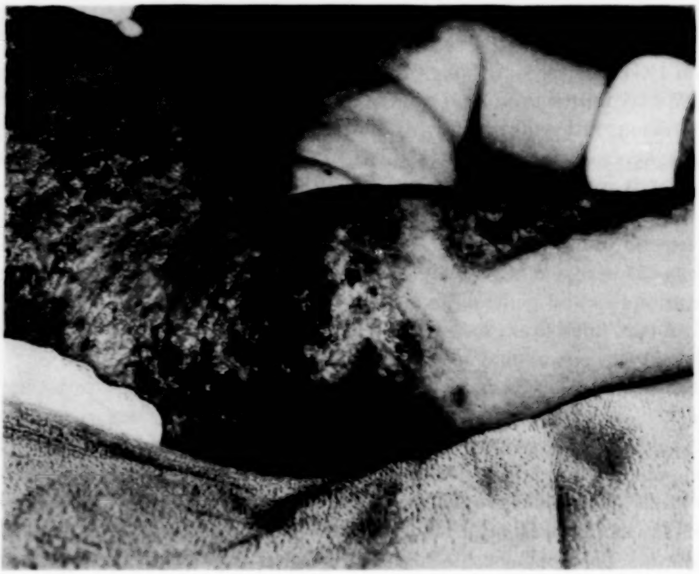

FIG. 1. Characteristic appearance of focal necrosis of granulation tissue observed 24 hours prior to the first positive blood culture which contained *Pseudomonas aeruginosa*. Death occurred in 48 hours in spite of Polymyxin therapy.

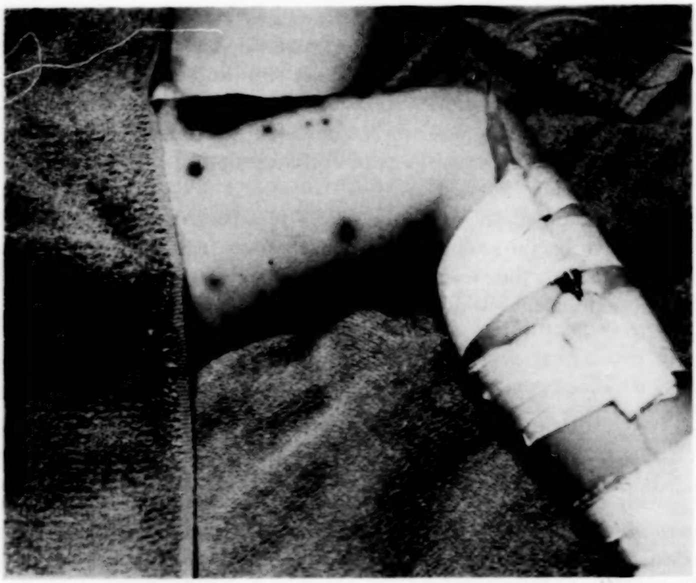

FIG. 2. Characteristic appearance of lesions resembling local Shwartzman phenomenon which appeared on both lower extremities and buttocks, and in the right eye, 24 hours prior to death. Cultures of the eye lesion and of all necrotic areas sampled grew out pure cultures of *Pseudomonas aeruginosa*.

In three patients, distant foci of necrosis occurred in unburned skin (Fig. 2). These were thought to be identical to the lesions described by Geppert (5), Markley (8), and Forkner (3). Sections from these areas also demonstrated the proliferation of gram-negative bacilli in and around small vessels, and cultures taken from necrotic areas grew out pure *Pseudomonas*. Clinically, these lesions begin as small areas of erythema which rapidly progress to necrosis of skin and subcutaneous tissue. It is quite possible that these tissues were sensitized by blood-borne organisms and that the provoking dose of endotoxin was supplied by accelerated destruction of intravascular organisms. Grossly and microscopically, these lesions resemble a local Shwartzman reaction (11).

In 1957, Thomas (12) stated that, "At the present time, there is no single primary action of endotoxin on any known tissue component which can be invoked to explain the numerous effects of endotoxin, and it is more likely that a mass of complicating and interlocking reactions, many of them secondary or tertiary, are involved. The sequence and timing of events seem as important as the events themselves in determining the final outcome." The many complicating and interlocking reactions may be even more confounding when we pass from the animal laboratory and attempt to delineate the numerous responses to endotoxin in man. We believe that the syndrome of gram-negative septicemia in the severely burned patient as described, Table 7, represents man's accumulative response to the physiological derangement of severe injury upon which immeasurable serum titers of endotoxin have been superimposed. Although the injection of endotoxin usually evokes hyperthermia and leukocytosis in the experimental animal, hypothermia and leukopenia may occur (9). Hypotension is the most consistent observation among investigators. The hypersensitivity-like reactions (local and generalized Shwartzman phenomena) are usually sequelae to properly timed injections of endotoxin. It is quite logical to assume that serum endotoxin titers are high in the burned patients with extensive wounds following invasion by, and destruction of, large numbers of bacteria. Methods for the measurement of these endotoxin levels are currently being investigated in this laboratory. Polymyxin B and colistin sulfate appear to have caused sterilization of blood in several patients but may have concurrently raised the endotoxin level to a lethal range by accelerating the rate of destruction of the microorganisms, as suggested by Fine (1) and Weil (13). Thus, antibiotic therapy in the patient with endotoxemia may be detrimental.

A generalized Shwartzman-like reaction has been seen in two patients with gram-negative septicemia on the basis of widespread intracapillary fibrinoid deposition in glomeruli. Graber (6) reported the first case following septicemia due to *Serratia marcescens* and postulated that a blockade of the reticuloendothelial system was followed by endotoxemia and death. The second generalized Shwartzman-like reaction followed septicemia due to *Pseudomonas aeruginosa*. In addition to the renal lesions, this patient showed focal areas of necrosis in granulation tissue and skin donor sites.

The therapy of patients with severe burns must include antibiotics. Penicillin is recommended during the first 3 to 5 days postburn to thwart the early complications caused by beta hemolytic streptococcus. Thereafter, antimicrobial therapy should be restricted to the treatment of specific infections. If signs of gram-positive septicemia appear, blood cultures should be taken at frequent intervals and therapy withheld until the organism is identified. However, if antibiotics are withheld until the laboratory identifies the bacteria in gram-negative septicemia, most of the patients will have died. Therefore, when focal necrosis in wounds is observed, Polymyxin B or colistin sulfate therapy is started immediately after drawing a blood culture. All patients with *Pseudomonas* septicemia have died in spite of this therapy. The septicemic syndrome which we equate with endotoxemia has not been reversed in any of our patients. The use of vasopressors, hydrocortisone, ganglionic blocking agents and Dibenzyline has been disappointing.

The authors believe that a significant area of potential improvement in burn mortality lies in the control of the effects of gram-negative bacteria infection. The failure of *in vitro* effective antibiotics to control the syndrome of *Pseudomonas* septicemia in burns suggests that the syndrome is due to endotoxemia rather than to invasion by living organisms. The control of this syndrome appears to require either protection against bacterial invasion or effective control of existent endotoxemia.

SUMMARY

Data have been presented which reveal that septicemia is present at death in over 60 per cent of fatal burns. These data also suggest an increase in the clinical importance of septicemia due to *Pseudomonas aeruginosa* in severely burned patients. While survival from staphylococcal and a number of other types of septicemia has been attained, *Pseudomonas* septicemia invariably has been fatal. Attention has been focused on the similarity of the clinical course in patients with gram-negative organism septicemia to endotoxemia. Experiences with local and generalized Shwartzman-like phenomena in severely burned patients have been described.

REFERENCES

1. Fine, J., Frank, E. D., Ravin, H. A., Rutenberg, S. H. and Schweinburg, F. B. The bacterial factor in traumatic shock. New England J. Med., **260:** 214–220, 1959.
2. Finland, M., Jones, W. F., Jr. and Barnes, M. W. Occurrence of serious bacterial infections since introduction of antibacterial agents. J.A.M.A., **170:** 2188–2197, 1959.
3. Forkner, C. E., Jr., Frei, E., III, Edgcomb, J. H. and Utz, J. P. Pseudomonas septicemia. Am. J. Med., **25:** 877–889, 1958.
4. Fraenkel, E. (a) Über Allgemeininfektionen durch den Bacillus pyocyaneus. Virchows Arch. path. Anat., **183:** 405, 1906; (b) Über die Menschenpathogenität des Bacillus pyocyaneus. Ztschr. Hyg., **72:** 486–522, 1912; (c) Weiter Untersuchungen über die Menschenpathogenität des Bacillus pyocyaneus. Ibid., **84:** 369–423, 1917; (d) Ein weiterer Beitrag zur Menschenpathogenität des Bacillus pyocyaneus. Ibid., **95:** 125–134, 1922.
5. Geppert, L. J., Baker, H. J., Copple, B. I. and Pulaski, E. J. Pseudomonas infections in infants and children. J. Pediat., **41:** 555–561, 1952.
6. Graber, C. D., Tumbusch, W. T., Rudnicki, R. P. and Vogel, E. H., Jr. Generalized Shwartzman-like reaction following Serratia marcescens septicemia in a fatal burn. Surg. Gynec. & Obst., **110:** 443–450, 1960.

7. Liedberg, N. C. F., Reiss, E. and Artz, C. P. Infection in burns. III. Septicemia, a common cause of death. Surg. Gynec. & Obst., **99:** 151–158, 1954.
8. Markley, K., Gurmendi, G., Chavez, P. M. and Bazan, A. Fatal Pseudomonas septicemias in burned patients. Ann. Surg., **145:** 175–181, 1957.
9. Olitzki, L., Avinery, S. and Koch, P. K. The hypothermic and adrenohemorrhagic effects of bacterial vaccines. J. Immunol., **45:** 237–248, 1942.
10. Rabin, E. R., Tumbusch, W. T., Graber, C. D. and Vogel, E. H., Jr. Clinical and anatomical features of fatal Pseudomonas infection in burned patients. To be published.
11. Shwartzman, G. Phenomenon of local skin reactivity to B. typhosus culture filtrate. J. Exper. Med., **48:** 247–268, 1928.
12. Thomas, L. Physiologic and pathologic alterations produced by the endotoxins of gram-negative bacteria. A.M.A. Arch. Int. Med., **101:** 452–461, 1958.
13. Weil, M. H. and Spink, W. W. The shock syndrome associated with bacteremia due to gram-negative bacilli. A.M.A. Arch. Int. Med., **101:** 184–193, 1958.
14. Yow, E. M. Development of Proteus and Pseudomonas infections during antibiotic therapy. J.A.M.A., **149:** 1184–1188, 1952.

SURGICAL MANAGEMENT OF PANCREATIC INJURIES

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The significance of pancreatic injuries was not appreciated until the last century when isolated reports began to appear in the literature, the first appearing in Lancet in 1827 (14). Only an occasional patient with an injury of this type was encountered, for 100 years later Schmeiden and Sebening were able to collect but 62 patients from the European clinics (13). The problem was reviewed by Culotta, Howard and Jordan in 1955 (2). At this recent date the rarity of pancreatic injuries was demonstrated by the fact that injuries resulting from external trauma occurred in only 1 to 2 per cent of abdominal wounds and the largest series reported in the English literature from a civilian institution included only 17 patients (9). Even in war time few injuries of this type were observed, the largest series being reported from World War II, when 62 patients were treated (11). In the Korean conflict only 9 pancreatic injuries were reported (12). The low incidence of trauma to this gland is due in part to its deep seated, relatively well protected position. It may be explained in part, however, by the fact that the pancreas is in close proximity to several structures which are often injured simultaneously, resulting in death prior to the time that the patient reaches medical care.

The present study consists of a review of all injuries of the pancreas resulting from external trauma treated surgically in the Baylor Affiliated Hospitals during a 20 year period ending June, 1960. It was surprising to find that in the last 5 years of this study, more injuries occurred than during the first 15 years.

CLINICAL MATERIAL

The records of 85 patients sustaining injuries to the pancreas resulting from external trauma were reviewed. In each instance the diagnosis was confirmed at operation. Eighty-two of these patients were treated at the Jefferson Davis Hospital and at the Veterans Administration Hospital, Houston, Texas, while 3 were private patients.

Seventy-four patients sustained penetrating injuries. No specific attempt was made to diagnose the pancreatic injuries preoperatively in these patients for penetration of the abdominal wall was considered sufficient indication for surgical exploration. Twenty-five patients sustained knife wounds. These were cleanly incised wounds, varying from superficial lacerations to more severe injuries

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TABLE I

Incidence of Associated Injuries

Liver	41
Stomach	40
Kidney	20
Duodenum	16
Spleen	15
Small Bowel	13
Major Arteries	13
Lungs	12
Colon	8
Inferior Vena Cava	7
Renal Vein	5
Portal Vein	3
Common Bile Duct	3
Gall Bladder	2
Rectum	1
Spinal Cord	1
Pericardium	1
Ureter	1

where a segment of the gland was transected, but in no instance was there complete transection. Bullet wounds caused trauma in 44 patients. In the majority of instances the wounding agent was a missile of low velocity; nevertheless, through-and-through penetration invariably resulted, and because of the soft nature of the pancreas there was some degree of blast effect in the gland immediately surrounding the missile tract. The most serious wounds occurred in the 5 patients sustaining shotgun blasts, for there were multiple penetrations as well as severe contusions. The lesions involved all segments of the gland but wounds were more common in the body and tail. Injuries to other viscera occurred in all but one patient with penetrating wounds. Associated lesions were most commonly seen in the stomach and liver, each of these organs being injured in more than half of the patients. Of particular significance were the injuries to major vessels, there being 28 lacerations of arteries or veins (Table I).

The remaining 11 patients (13 per cent) suffered from blunt trauma. In this group all types of injuries were noted including complete transection, contusion and laceration. The incidence of associated injury involving other organs was less than seen in patients with penetrating trauma for in 7 of the 11 patients the pancreas was the only organ damaged.

TREATMENT

In 80 patients, 4 surgical procedures were employed. The most common treatment was simple drainage, used in 45 patients. With this type of therapy a high incidence of pancreatic fistula was anticipated; despite this it was chosen for a number of reasons. In some patients the severity of the injury to other organs was so great that the minimum procedure compatible with the life of the patient seemed desirable. In other instances the pancreatic laceration was so small that no specific repair seemed indicated. In many patients, however, pancreatic repair was not accomplished simply because the surgeon believed that suture repair of the pancreas would not significantly improve the results obtained. Thus drainage was the procedure employed in almost all patients treated more than 10 years ago. In recent years, there has been increasing interest in attempts to repair the pancreas or to remove damaged areas by excision. The wound was repaired by suture in 25 patients. In each, drainage was also instituted after suture had been accomplished. Caudal resection was performed in 9 patients. In the first 15 years of this study caudal resection was accomplished in only one instance, the remaining patients being treated within the past 5 years. In 8 of the patients treated by caudal resection, trauma had been sustained by a gunshot or a shotgun and the tail of the pancreas was severely injured. One patient with a severe blast injury involving the head of the pancreas was treated by pancreatoduodenectomy.

In one patient the pancreatic wound was not appreciated at the time of the original exploration for a penetrating wound and treatment consisted of repair of a stab wound of the stomach. The patient subsequently developed a pseudocyst of the pancreas which required treatment and led to the diagnosis of pancreatic injury. Four patients expired during operation before specific therapy to the pancreatic lesion was instituted.

At the time of pancreatic exploration the pancreatic duct was not specifically identified except in one patient. Incomplete transection of the head of the gland had resulted from a severe blow to the abdomen. When first seen the transection appeared to involve the duct, and primary repair of the pancreas with reconstruction of ductal continuity was planned. The duodenum was opened and a polyethylene tube passed into the orifice of the pancreatic duct. The pancreatic duct, thus identified throughout its length was found to be completely intact, the gland being almost totally transected except for this structure. Treatment by simple drainage was instituted with the formation of a fistula which closed in approximately 3 months.

RESULTS

Mortality. Fifteen (18 per cent) of the 85 patients expired during operation or during the immediate postoperative period. Shotgun wounds, as might be anticipated, were associated with the highest mortality, 40 per cent, while knife wounds were associated with the lowest mortality, there being only one death in this group (Table II). This patient had sustained multiple injuries of other organs as well as of the pancreas. The mortality rate for penetrating wounds was twice that for wounds resulting from blunt trauma. As previously noted, there was an extremely high incidence of associated injuries, and death resulted from these injuries rather than the pancreatic wounds. In fact, in no patient was death attributed directly to the pancreatic wound. The significance of associated injuries is particularly well exemplified in our analysis of the wounds treated in the past 5½ years (Table III). These data demonstrate graphically the prognostic importance of multiple injuries, for there were no deaths in patients sustaining injury only to the pancreas or to the pancreas and one other organ, irrespective

TABLE II

Mortality as Related to Type of Injury

Type of injury	Number of patients treated	Mortality	
		Number	Per cent
Penetrating or perforating	74	14	19
Shotgun	5	2	40
Bullet	44	11	25
Knife	25	1	4
Blunt	11	1	9
Automobile accident	5	1	20
Fall	6		
Total	85	15	18

TABLE III

Mortality According to Associated Injuries 1956 to 1960

Number of patients treated	Associated organs or vessel injury	Mortality	
		Number	Per cent
3	0	0	0
11	1	0	0
12	2	2	16
6	3	1	17
20	4*	7	35

* This group of patients included four or more associated injuries.

of the mechanism of wounding; but with the increase in the number of organs or vessels injured, there was a steady rise in mortality. The mortality rate was 35 per cent in those patients sustaining injuries to 4 or more organs. Wounds to major vessels constituted the primary factor in mortality, for hemorrhage was a direct cause of death in 12 patients. Six deaths occurred in the operating room. As previously mentioned 4 patients expired before any attempt to treat the pancreatic wound was instituted while 2 patients underwent caudal resection of the gland. The remaining patients died of hemorrhage within the first 24 hours postoperatively. This problem is well exemplified by one patient who sustained a gunshot wound with associated injuries to the stomach, liver, superior mesenteric and middle colic arteries, as well as the vena cava, the left renal and splenic veins. During the operative procedure and in the immediate postoperative period 37 pints of blood were administered. Despite this therapy he remained hypotensive and in the postoperative period developed a bleeding tendency which failed to respond to vigorous therapy. Death occurred $5\frac{1}{2}$ hours following completion of the operative procedure. "Lower nephron nephrosis" with uremia resulted in 2 deaths and one death was attributed to postoperative aspiration pneumonia.

An analysis of mortality according to the types of treatment revealed that the lowest mortality rate (9 per cent) occurred in patients treated with drainage, and the mortality rate was similar (12 per cent) in patients treated by suture of the pancreatic wound and drainage. The mortality rate was considerably higher in patients treated by caudal resection (33 per cent), but as previously noted, these patients had sustained severe injuries. The one patient treated by pancreatoduodenectomy expired. It was the opinion of the operating surgeon that trauma to the head of the pancreas was so great that removal was indicated.

Complications of Pancreatic Trauma

Pancreatic Fistula. The most common complication following surgical therapy was pancreatic fistula (Table IV), occurring in 23 (33 per cent) of the 70 patients surviving the operation. The incidence of fistula was higher in patients with blunt trauma (50 per cent) than in patients with penetrating wounds (28 per cent). Fistulas occurred primarily in those patients sustaining extensive laceration or crushing injury to the pancreas. The location of the injury in the pancreas was of significance as only 10 per cent of patients with penetrating wounds of the tail developed fistulas compared to 43 per cent of those with injuries in the head (Table V). The highest incidence of fistula occurred in patients treated by simple drainage, fistulas developing in 40 per cent of these. The incidence was much less in patients having suture repair of the gland, 23 per cent. This difference in frequency of fistula formation, however, was due to the striking difference in the group of patients sustaining simple lacerations. In this group there were 8 patients treated by suture repair and drainage with no fistula formation while among 13 patients with simple drainage 5 patients (38 per cent) formed fistulas. In patients having perforating wounds the incidence was the same following simple drainage or suture repair.

None of the patients died as a result of fistula formation. Most were minor and closed spontaneously within a few weeks; only one patient required surgical therapy. This patient sustained blunt trauma to the pancreas resulting in complete transection of the neck of the gland which was originally treated by drain-

TABLE IV

* *Incidence of Pancreatic Complications as Related to Types of Injury*

Type of injury	Number of patients treated	Complications		
		Fistula	Pseudocyst	Abscess
Penetrating Injuries	60	17	1	1
Knife	24	5	1	1
Bullet	33	11	0	0
Shotgun	3	1	0	0
Blunt Injuries	10	6	3	1
Total (survivors)	70	23	4	2

* This table relates only to surviving patients.

TABLE V

The Incidence of Pancreatic Fistula According to Location of Penetrating Wound (Survivors)

Site of injury	Number of patients	Fistula	
		Number	Per cent
Head	14	6	43
Body	26	9	35
Tail	20	2	10
Total	60	17	28

age. A complete fistula of the body and tail of the gland developed while the proximal transected end closed spontaneously. Control of the fistula was accomplished by a second operation in which an anastomosis of the tail of the gland to a Roux-en-Y loop of the jejunum, was performed thereby preserving pancreatic secretion in this 17 year old boy. Exclusive of this patient only 2 fistulas drained for more than 2 months.

The management of pancreatic fistula has been well documented in the literature. The basic principles include accurate collection of all pancreatic juice with replacement of volume and electrolyte content either by intravenous fluids or by refeeding the juice which is collected. The skin must be protected, although the digestive action of pure pancreatic juice is minimal compared to the severe digestive action of material from duodenal fistulas. Of importance is the maintenance of an adequate diet by mouth, supplying adequate calories, proteins, and vitamins. The value of adequate nutrition far out-weighs the theoretic advantage of decreasing pancreatic secretion by limiting alimentation. Parasympathetic blocking agents have been of little value in our experience.

Pseudocysts. The other complication of significance was pseudocyst formation, which occurred in 4 patients (6 per cent) of the survivors. Three (30 per cent) of the patients sustaining blunt trauma developed this complication while only one (2 per cent) followed penetrating trauma. Three were treated by external drainage and only one by internal drainage, though at the present time we prefer internal drainage in most instances. In no patient was development of pseudocyst or the treatment thereof the cause of death.

Trauma ranks second only to pancreatitis as a cause of pseudocyst in the adult. Pseudocysts usually follow blunt trauma for perforating injuries are explored early and the pancreatic wound is drained, thereby permitting the formation of a fistula rather than a pseudocyst in most patients (7).

Abscess. Only 2 patients developed abscesses which could be specifically attributed to the pancreatic injury. One of these sustained blunt trauma. The pancreatic injury was unrecognized until an abscess developed. The second abscess developed in a patient with a penetrating wound in which the pancreatic wound was unrecognized until an abscess developed. Drainage was accomplished in both instances with survival.

Pancreatitis. Some degree of inflammation undoubtedly occurs as a result of injury, and a rise in the serum amylase concentration was observed in several patients; but the pancreatitis was not of sufficient severity to be recognized clinically or to increase morbidity during postoperative convalescence.

DISCUSSION

In 1948 Hart and Lisa reported a 10 year review of the literature concerning isolated non-penetrating injuries of the pancreas and concluded that although rare, this lesion was probably the most common type of pancreatic injury encountered due to external trauma (6). Evidence to date indicates that this was an erroneous conclusion as exemplified by the current series in which only 13 per cent of the injuries were due to non-penetrating trauma. Despite the fact that an increasing number of patients sustain blunt trauma as a result of vehicular accidents and injury resulting from accidents involving various types of machinery, more abdominal viscera are still injured from penetrating wounds than blunt trauma and pancreatic wounds reflect the same pattern as wounds of the stomach or colon. The injuries due to blunt trauma are of particular importance, however, for they constitute a somewhat different problem from those resulting from penetrating wounds. The pancreas, in its retroperitoneal position may not produce symptoms and physical findings as dramatic as those resulting from injury to organs inside the peritoneal cavity. Thus delay in diagnosis is frequently reported, and delay occurred in several of our patients. In order to decrease this delay and aid in diagnosis serum amylase concentrations should be obtained in every patient suspected of having blunt trauma to the abdomen; an elevated serum amylase concentration should be considered strong evidence of pancreatic injury. The delay in diagnosis and the severe contusion which is frequently found in blunt injuries of the pancreas have been associated with a higher incidence of complications than seen with penetrating wounds. Not only is this true in the current series, but also in those patients reported by others. In a review of 49 patients reported in the literature between 1945 and 1960, exclusive of those in this series, it was found that 31 per cent developed pseudocyst and 33 per cent developed fistula (1–5, 9). The mortality rate, however, was only 4 per cent, for the pancreas was the only organ injured in many patients. This high incidence of complications and the low mortality rate again demonstrate the fact that pancreatic wounds are associated with morbidity but the pancreatic wound rarely is the direct cause of death.

A review of the data in the current series suggests a rational approach to the treatment of pancreatic injuries. Cleanly incised wounds may be successfully sutured with a reduction in the incidence of pancreatic fistula. Penetrating wounds with loss of pancreatic tissue and blast effects surrounding the tract do not respond well to suture, for an accurate approximation of the anterior and posterior capsules of the pancreas may be extremely difficult. In these patients simple drainage seems to offer comparable results with less hemorrhage and decreased operating time. Caudal resection of the pancreas seems justified in only the occasional patient, when the pancreatic wound is the only wound, the patient is in good physical condition, and the pancreas seems to be damaged beyond repair. It would appear that an attempt to remove the tail of the pancreas is likely to add unnecessarily to the trauma and possibly to the blood loss in patients with severe multiple injuries. In a critically injured patient removal of obviously necrotic tissue, hemostasis, and adequate drainage may be the preferable procedure, accepting the somewhat increased risk of pancreatic fistula. Pancreatoduodenectomy is probably never indicated in patients with pancreatic trauma, for this extensive procedure will be attended with a high operative mortality rate.

Complete transection of the pancreas is a special problem which was encountered only once in the current series. In recent years reports in the literature have described definitive procedures for preserving pancreatic function under such circumstances. Doubilet and Mulholland have treated such injuries by placing a polyethylene tube into the pancreatic duct across the site of injury with successful reconstruction of ductal continuity (3). Another type of repair which has been reported consists of closing the proximal transected end and anastomosing the body or tail of the pancreas to a Roux-en-Y loop of jejunum, as was utilized as a secondary procedure in one of the patients herein reported (8). Both of these procedures may be utilized successfully and attempts to preserve pancreatic tissue may be of importance, particularly in the young, growing individual.

The mortality from treatment of pancreatic wounds has decreased significantly from that reported during World War II when the mortality was 56 per cent. In the current series, the mortality rate was much lower, though the prognosis is grave in the patient sustaining wounds of multiple viscera. It does not appear that improvement in management of pancreatic wounds per se is likely to result in a further decrease in mortality rate, rather, decrease in mortality rates will be due to improvement in the total care of severely wounded patients.

REFERENCES

1. Blandy, John P., Hamblen, Daniel L. and Kerr, W. F.: Isolated Injury of the Pancreas from Non-Penetrating Abdominal Trauma. Brit. J. Surg. **202:** 150, 1959.
2. Culotta, Ralph J., Howard, John M., and Jordan, George L., Jr.: Traumatic Injuries of the Pancreas. Surgery **40:** 320, 1956.
3. Doubilet, Henry, and Mulholland, John H.: Surgical Management of Injury to the Pancreas. Ann. Surg. **150:** 854, 1959.
4. Guzzo, Carl P.: Injuries of the Pancreas. J. Med. Soc. N. Jersey **54:** 235, 1959.
5. Hannon, Donald W., and Sprafka, Joseph: Resection for Traumatic Pancreatitis. Ann. Surg. **146:** 136, 1957.
6. Hart, J. F., and Lisa, J. R.: Isolated Non-Penetrating Injuries of the Pancreas: Ten Year Review of Literature and Report of Case. New York J. Med. **48:** 903, 1948.
7. Howard, John, and Jordan, George L., Jr.: *Surgical Diseases of the Pancreas.* J. B. Lipppincott Company. Philadelphia, 1960.
8. Letton, A. H., and Wilson, John Page: Application of the Roux-en-Y Anastomosis to Diseases of the Pancreas. J. Internat. Coll. Surg. **32:** 123, 1959.
9. Matthewson, C., Jr., and Halter, B. L.: Traumatic Pancreatitis With and Without Associated Injuries. Am. J. Surg. **83:** 409, 1952.

10. NEWTON, DWIGHT, AND NICHOL, WILLIAM: Pancreatic Pseudocysts and Fistulae. A.M.A. Arch. Surg. **75:** 83, 1957.

11. POOL, L. H.: *Wounds of the Pancreas. Surgery in World War II.* Chapter XIX. Office of the Surgeon General, Washington, D. C., 1955.

12. SAKO, Y., ARTZ, C. P., HOWARD, J. M., BRONWELL, A. W., AND INCIR, F. K.: A Survey of Evacuation Resuscitation and Mortality in a Forward Surgical Hospital. Surgery **37:** 602, 1955.

13. SCHMEIDEN, V., AND SEBENING, W.: Surgery of the Pancreas. Surg. Gynec. & Obst. **46:** 735, 1928.

14. TRAVERS, B.: Rupture of the Pancreas. Lancet **12:** 384, 1827.

THE INCIDENCE OF REACTIONS FOLLOWING THE ADMINISTRATION OF TETANUS ANTITOXIN

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In the pre-antibiotic era the most significant advance in the treatment of infectious disease was the introduction of specific serum therapy. The demonstration that an infected host produced specific circulating antibodies against many invading organisms and that these antibodies would frequently protect against subsequent reinfection provided the basis for the first truly specific therapy for infectious disease. Administration of specific antibodies artificially produced in laboratory animals gave the physician his first effective weapon against such diseases as tetanus, meningococcal meningitis, and pneumococcal pneumonia.

The success of specific antisera in the treatment of many infections encouraged the use of these preparations as preventive agents in well individuals. Although the immunity conferred by passive transfer of circulating antibodies was temporary and incomplete, it frequently served a useful purpose in the protection of individuals subjected to special risks. As with all new therapeutic agents, however, the administration of donor antibodies from animals of a different species soon proved to have unsuspected hazards. Both immediate and delayed reactions of varying degrees of severity were frequently encountered, although the number of these decreased as more purified preparations became available. Nevertheless, administration of heterologous serum still causes sufficient morbidity to warrant caution in its use.

During the past two decades the most frequent use of antitoxin has been for the prophylaxis of tetanus in individuals sustaining traumatic injury. The fact that passive immunity against tetanus is so frequently deemed necessary is in itself an indictment of the success of our preventive medical programs. Of all forms of artificial active immunization which have been developed, none offers

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surer protection than the administration of tetanus toxoid. Its efficacy in providing at least 99.9% protection against disease is unequalled by any other prophylactic agent (6, 16). Nevertheless, only two large groups can be presumed with any degree of accuracy to have been immunized against tetanus. These are veterans of service in the Armed Forces and most children under the age of 18. Even for this latter group the presumption cannot be made with any degree of certainty, since the almost universal use of diphtheria-pertussis-tetanus immunization in childhood is only now becoming a reality. Hence the physician treating traumatic injuries is constantly faced with a problem of whether or not to administer tetanus antitoxin.

Although the number of reported cases of tetanus in the United States has declined from 579 in 1949 to 445 in 1958, it has been estimated that only 20% of the cases are reported (11). The case-death ratio has declined from 90% to 60% in the same period (10). Among some groups, such as narcotic addicts who account for much of the tetanus in urban areas, the mortality approaches 100%. How much greater the incidence of tetanus might be if prophylactic antitetanus therapy were not given routinely is impossible to estimate.

In addition to considering the low incidence of the disease, the physician treating open wounds must weigh the disadvantages of tetanus antitoxin. These disadvantages include the following:

1. The ineffectiveness of the usual prophylactic dose of 1,500 units of tetanus antitoxin in some cases.

2. The possibility that passive immunization may sensitize the individual to horse serum.

3. The possibility of a serious immediate (anaphylactic) reaction in previously sensitized individuals.

4. The possibility of delayed reactions such as serum sickness and, to a lesser extent, brachial plexus palsy and other rare manifestations of serum disease.

All of these factors must be weighed by the physician before the decision to administer tetanus antitoxin is made, but the risks of some of them are easier to evaluate than others. The fact that the customary prophylactic dose of 1,500 units of antitoxin will not necessarily prevent the development of tetanus, especially where the wound is grossly contaminated or when treatment has been delayed, has only recently been appreciated. There are numerous recorded instances in which 1,500 units of antitoxin has failed to prevent clinical tetanus, including a case treated by one of us (5, 8, 17, 19). Some authorities now recommend that any individual deemed to need prophylactic antitoxin should receive as much as 10,000 units, and dosages as high as 30,000 units have been suggested (12, 18).

The possibility that administration of antitoxin may sensitize the individual to horse serum must also be considered as a serious disadvantage, since future circumstances may arise in which the need for horse serum may be considerably more urgent.

Immediate anaphylactic reactions, although serious, can usually be avoided By adequate sensitivity testing, leaving the possibility of delayed reactions as the principal unknown factor. Such serious complications as brachial plexus palsy, although well-documented, are extremely rare, with a total of only 127 cases reported up to 1958 (21).

Thus the most likely complication of tetanus antitoxin therapy remains serum sickness, but the actual incidence of morbidity from this cause is extremely difficult to determine.

Since the symptoms of serum sickness usually appear one or two weeks after treatment for the initial injury, the patient often seeks therapy from a different physician or facility than the one treating the original injury. The difference in symptoms between serum sickness and the initial traumatic injury also often influence the patient to visit an internist or other type of specialist rather than the surgeon who administered the antitoxin. For this reason, many surgeons in hospital emergency rooms are not aware of how frequently patients whom they have given antitoxin subsequently develop serum sickness. Nevertheless, a knowledge of the relative risks of this complication is essential if an intelligent judgment is to be made as to the need for tetanus antitoxin in each case.

Early reports on the frequency of this complication giving figures from 16% to 24% (3) are based on experiences of a generation ago, when the use of antitoxin was more indiscriminate and the preparations available contained considerably more nonspecific foreign protein. Nevertheless, the few recent studies using modern purified antitoxin continue to show the incidence of serum sickness to be between 5% and 10% (14, 15). The present study was carried out to determine more accurately the present-day risks in the administration of tetanus antitoxin when employing the usual testing procedures for sensitivity and with careful evaluation of the need for prophylaxis in each case.

METHOD

The hospital records of 2,366 consecutive patients treated in 1959 for open wounds in the emergency unit of The New York Hospital were reviewed. These patients, comprising a total of one year's experience, included all lacerations, puncture wounds, bites, abrasions, and burns treated without immediate admission to the in-patient service (Table I). Major soft tissue injuries and major open fractures, which were admitted directly to the hospital, were not included.

TABLE I

Open Wounds Treated in 1959 in the New York Hospital Emergency Unit

Type of wound	Number	Per cent
Laceration	1,511	64
Puncture wound	211	9
Bite (human & animal)	144	6
Crush Injury	61	3
Burn	170	7
Abrasion	259	11
Total	2,366	100

TABLE II

Antitetanus Prophylaxis given for 2,366 Open Wounds

	Number		Per cent	
Antitoxin (with or without toxoid)	313		13	
Toxoid alone	1,440		61	
(Booster dose)		(446)		(19)
(Active immunization started)		(591)		(25)
(Reason not stated)		(403)		(17)
Immunity status considered satisfactory	43		2	
No immunization given	570		24	
Total	2,366		100	

Three fourths of all these patients (1,753) received some form of prophylaxis against tetanus, and in an additional 43 the immunity status was considered satisfactory by history (Table II). It is noteworthy that for only 313 (13%) was tetanus antitoxin considered necessary. Nearly two thirds (1,440) of this group received only tetanus toxoid, and for 446 (19%) of these 1,753 patients the hospital record states it was given as a booster dose. In general, a booster dose was prescribed whenever previous active immunization could be reasonably established regardless of the length of time which had elapsed since the initial series. In an additional 591 patients active immunization was initiated with tetanus toxoid without evidence of previous immunization, but for the remaining 403 patients receiving toxoid, no explanation was given in the hospital records. Of the remaining 570 patients 12 refused any type of immunization, and 558 patients were considered by the examining physician to need no tetanus prophylaxis other than wound care and, in some cases, antibiotics. Nine hundred and eight (42%) of all patients were followed. There were no cases of clinical tetanus in the patients followed.

SENSITIVITY TESTS

Intradermal tests for sensitivity to tetanus antitoxin were recorded in the hospital records of 608 patients. These tests were carried out by the injection of 0.1 ml of a 1:10 dilution of either equine or bovine antitoxin (Table III). The discrepancy between the number of patients receiving tetanus antitoxin in Table II (313) and the number exhibiting a negative intradermal test for tetanus antitoxin hypersensitivity in Table III (268) is due to the fact that a sensitivity test to tetanus antitoxin was not recorded in the hospital charts of 45 patients. Although it is assumed that these individuals were tested for sensitivity to tetanus antitoxin, they were not included in Table III. It is highly significant that over half of all patients tested with standard equine antitoxin were considered to have a positive reaction. Forty eight of these patients for whom the need for prophylaxis appeared most urgent were retested with bovine antitoxin. Two thirds of

TABLE III

Intradermal Tests for Tetanus Antitoxin Hypersensitivity

Type of antitoxin	No. tested	(%)	Positive	(%)	Negative	(%)
Equine antitoxin (0.1 ml, 1:10 dilution)	560	(100)	308	(55)	252	(45)
Bovine antitoxin (0.1 ml, 1:10 dilution)	48	(100)	32	(67)	16	(33)
Total tests	608		340	(56)	268	(44)

these patients were also sensitive to bovine antitoxin, a fact that seriously limits the usefulness of the bovine preparation.

Because of the rapid elimination of tetanus antitoxin from the circulation of individuals sensitive to horse serum, desensitization of individuals giving positive skin tests was not attempted (4, 13). For these individuals reliance was placed on good wound care and, in addition, prophylactic antibiotics in some cases. Many of these individuals also received tetanus toxoid as the start of an immunization series, although it was realized this offered no protection for the current injury. Nevertheless, we feel strongly that the physician caring for an injured individual should always initiate active immunization with tetanus toxoid whenever the opportunity presents itself. This responsibility also includes arrangements for completion of the series and, equally important, for giving the patient a record of his immunization.

SERUM SICKNESS REACTIONS

Follow-up of the patients receiving antitoxin was possible in 46% of cases (144 of 313). Of these, 144 received equine antitoxin, and 10 were given the bovine preparation (Table IV). No *immediate* local or general reactions appeared in either group, indicating the effectiveness of the skin test as a screening procedure. Only eight patients (5.5%) subsequently developed generalized reactions interpreted by the examining physician as serum sickness (Table V). These reactions consisted of varying degrees of generalized rash, hives, swelling, and pruritus, developing from two to seven days after the administration of antitoxin. One of these patients also received penicillin at the time of injury, so that the delayed reaction may have represented a sensitivity to this drug rather than to horse serum. Only one individual developing serum sickness needed admission to the hospital for this complication. In fact, a review of hospital admissions for the past 25 years reveals only 32 patients admitted to this institution for allergic reactions to tetanus antitoxin out of over 800,000 consecutive admissions.

Of the 1,440 patients receiving tetanus toxoid, 616 (43%) were followed, and among this group there were no immediate or delayed general reactions, con-

TABLE IV

Serum Sickness Reactions to Tetanus Antitoxin

Type of antitoxin	No. of patients given antitoxin	No. of patients developing serum sickness	(%)
Equine antitoxin	134	8	(6.0)
Bovine antitoxin	10	0	
Total doses	144	8	(5.5)

TABLE V

Serum Sickness Reactions to Tetanus Antitoxin

Wound	Sex	Age	TAT skin test	TAT dose	Other drugs administered for injury	Days after therapy reaction developed	Therapy given for reaction
Tendon laceration (finger)	M	33	Neg.	1,500 u. equine	Procaine Tetanus toxoid	10	None
Dog bite (leg)	M	42	Done—result not recorded	Given—dose not recorded	None	7	Epinephrine Antihistamines
Laceration (finger)	F	?	Not recorded	1,500 u. equine	Penicillin Procaine Tetanus toxoid	7	None
Laceration (finger)	F	45	Neg.	1,500 u. equine	Tetanus toxoid	7	None
Splinter (foot)	F	31	Neg.	1,500 u. equine	None	4	Epinephrine Antihistamines (admitted)
Laceration (finger)	F	18	Neg.	1,500 u. equine	Tetanus toxoid	7	Steroids Epinephrine Antihistamines
Abrasions (arms and leg)	F	28	Neg.	1,500 u. equine	None	6	Epinephrine Antihistamines
Laceration (finger)	M	45	Not recorded	3,000 u. equine	Xylocaine Tetanus toxoid	2	Steroids

firming numerous statements that reactions to this product are extremely rare (16).

DISCUSSION

The finding that 55% of all individuals in this series tested with horse serum were sensitive to the product poses a serious problem in tetanus prophylaxis.

Only 19% of these injured individuals could be determined with any reasonable certainty to have received previous active immunization against tetanus. This dilemma forces the emergency room physician to administer horse serum to large numbers of individuals, a significant number of whom will develop serum sickness reactions despite the most careful testing procedures. It is paradoxical that the only disease for which horse serum is now used prophylactically is also the same disease for which we possess the single most effective immunizing agent. This paradox constitutes a serious indictment of our preventive medical programs and of the medical profession itself for failing to utilize adequately the contributions of medical research.

Another problem revealed in these figures is the inadequate information most persons have concerning their own immunization status. It is highly probable that considerably more than 19% of these individuals had received tetanus toxoid at some time in the past, but since they had no knowledge or written record of this event, the physician was forced to consider the use of tetanus antitoxin. This emphasizes the need for some type of uniform immunization roster on a convenient wallet-size card which would not only provide valuable information on previous immunizations to a physician treating an injury but would also serve as a reminder to the physician of the necessity for adequate initial and booster immunizations for all his patients.

At the present time the physician treating a traumatic injury has no alternative to offering some type of tetanus prophylaxis. He may rely entirely upon good wound care, including thorough cleansing and removal of all foreign material and devitalized tissue; but this would ignore the fact that many cases of tetanus develop from extremely minor or even inapparent wounds (1, 7). If evidence of previous active immunization cannot be obtained, he is forced to consider the use of passive immunization with tetanus antitoxin. If after a negative skin test he administers tetanus antitoxin, he can expect that at least 5% of his patients will subsequently develop serum sickness reactions. Most of these will be mild, and only an occasional patient will need hospitalization for this cause. If the skin test is positive, he faces a further dilemma. Surveys by the authors indicate that desensitization of individuals giving positive skin tests is still widely practiced throughout the country (9). However, some authors now feel that such procedures are of little value, since the divided doses of antitoxin are rapidly neutralized by circulating antibodies in the sensitive individual, so that little, if any, protection is conferred. Use of bovine preparations may be considered, but in our experience two thirds of individuals sensitive to horse serum are also sensitive to bovine serum. This leaves the physician with no alternative but to rely on good wound care and prophylactic antibiotics, which have been shown to have a definite protective effect against the tetanus organism (2, 10, 20). In any case, whatever the decision of the physician for treatment of the current injury, active immunization should be initiated, arrangements made for completion of the series, and the patient given a record of his immunization.

For any individual for whom a history of active immunization any time during the preceding ten years can be obtained, reliance may be placed with safety on a booster dose of tetanus toxoid. It is probable that such a booster dose will give protective levels of antibody after considerably longer periods. We are now carrying out studies to clarify this point.

SUMMARY

The hospital records of 2,366 patients sustaining traumatic injuries during a period of one year and treated in a hospital emergency unit are reviewed. Sensitivity tests for equine tetanus antitoxin were carried out on 560 persons, and of these, 308 (55%) were found to be sensitive to this preparation. Forty-eight persons sensitive to equine antitoxin by skin test were also tested with bovine antitoxin. Two thirds of these were also sensitive to the bovine preparation. Of the 134 patients followed who were given equine antitoxin after negative skin testing, only eight (6%) subsequently developed serum sickness reactions. None of the ten individuals receiving bovine antitoxin developed such a reaction. Only one individual developing serum sickness needed admission to the hospital. Of 616 individuals followed after receiving tetanus toxoid, none developed either immediate or delayed generalized reactions.

REFERENCES

1. Altemeier, W., Culbertson, W., and Gonzalez, L. Clinical experiences in the treatment of tetanus. Arch. of Surg., **80:** 977–984, 1960.
2. Anwar, A., and Turner, T. Antibiotics in experimental tetanus: In vitro and in vivo studies. Bull. Johns Hopkins Hosp., **98:** 85, 1956.
3. Clairborne, L. N. The ophthalmic test for sensitivity to horse serum. J.A.M.A., **98,** 1, 718, 1932.
4. DuBos, R. *Bacterial and Mycotic Infections in Man*, p. 358. J. B. Lippincott Co., Philadelphia, 1958.
5. Edsall, G. Specific prophylaxis of tetanus. J.A.M.A., **171:** 417 (Sept. 26) 1959.
6. Glenn, F. Tetanus, preventable disease. Ann. Surg., **124:** 1,030, 1946.
7. Hubbard, J. *The Early Detection and Prevention of Disease*, p. 313. Blakiston Co., 1957.
8. Martini, M. Prophylactic failure of 1,500 units of tetanus antitoxin: Report of two cases. California Med., **82:** 189–191 (March) 1955.
9. McCarroll, J. and Skudder, P. A survey of hospital emergency facilities and services. Hospitals. (In Press)
10. McDonald, R., Chaikoff, L. and Truant, J. An analysis of prophylactic measures in experimental tetanus. Surg. Gyn. & Ob., **110:** 702, 1960.
11. Morbidity and Mortality (Annual Supplement). U. S. Public Health Service. (October 30) 1959.
12. Press, E. Desirability of the routine use of tetanus toxoid. New Eng. J. Med., **239:** 50 (July 8) 1948.
13. Prudovsky, S. and Turner, T. Studies on the prophylaxis and treatment of tetanus. Bull. Johns Hopkins Hosp., **102:** 55, 1958.
14. Scribner, L. H. Serum sickness following injections of tetanus antitoxin. Med. Arts & Sciences, **12**(2): 21–77, 1958.
15. Singleton, A. O. and Little, H. M. The use of antihistamic agent in preventing serum reactions. Surgery, **40**(4): 784–786 (October) 1956.
16. Sherman C. D. and Barnhouse D. H. Tetanus: A preventable disease. Surg., Gyn., & Ob. **107:** 143, 1958.

17. Skudder, P. and Inglis, A. Tetanus: Report of a case receiving prophylactic dose of 1,500 units tetanus antitoxin. (In Preparation)
18. Spaeth, R. Tetanus: Its prevention. Nebraska Med. J., **41:** 224 (June) 1956.
19. Stafford, E., Tetanus: Active and passive immunization. J.A.M.A. **173:** 539, 1960.
20. Taylor, W. and Novak, M. Tetanus: Prophylaxis of tetanus with penicillin procaine. Ann. Surg., **133:** 44–49, 1951.
21. Tyler, L. T., Kaplan, I. E., and Levy, R. W. Brachial plexus paralysis following administration of tetanus antitoxin. Am. J. Surg., **95**(4): 668–672. 1958.

TETANUS

Editorial Note. Prophylaxis against tetanus poses a problem emphasized by the preceding paper dealing with reactions to tetanus antitoxin. In accepting that paper for publication the Editorial Board felt it might be helpful to readers of the Journal of Trauma could we reproduce the pages on prophylaxis against tetanus from the new manual on soft tissue trauma (1) prepared under the auspices of the Committee on Trauma of the American College of Surgeons. That Committee, the American College of Surgeons, and the publishers, W. B. Saunders Company, have kindly granted permission for reproduction of this article, which is reprinted herewith.

VI. Tetanus

A. Principles of Prophylaxis against Tetanus*

1. Through cleansing and debridement of wounds, at times with the wound left open, are the most important parts of the prophylaxis against tetanus.

2. The need for and method of prophylaxis against tetanus must be determined for each patient according to individual indications. It cannot be standardized.

3. The skin and eye tests for sensitivity to horse serum and a carefully taken history of possible allergic manifestations are a medical responsibility. Before giving tetanus antitoxin to a patient, the physician must determine whether the danger of tetanus exceeds the danger of anaphylaxis.

4. Passive immunity with tetanus antitoxin is short-lived, but, the greater the dosage of tetanus antitoxin, the longer the duration. In the opinion of the majority of this Subcommittee, 1500 units of tetanus antitoxin are of limited and transitory value and are inadequate dosage; if tetanus antitoxin is indicated, the dosage should be a minimum of 5000 units. Tetanus can develop even with passive immunity, particularly after the first week.

5. The patient who has had horse serum previously may neutralize a new injection rapidly even without a positive skin or eye test. The patient sensitive to horse serum is extremely likely to neutralize it rapidly. A patient who has not received an injection of horse serum previously may be sensitive to it.

6. Routine use of alum-precipitated toxoid appears advisable for basic immunization and booster injections. Fluid toxoid may be used as a booster injection, but not when simultaneous passive-active immunization is being provided. Authorities are not in full agreement as to the advantages and disadvantages of each type of toxoid.

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* Subsections A, B, and C, on prophylaxis against tetanus, have been prepared by the Subcommittee on Prophylaxis against Tetanus of the Committee on Trauma, American College of Surgeons. The Subcommittee, including advisory members, is composed of William A. Altemeier, Geoffrey Edsall, Stanley F. Hampton, Howard E. Snyder, Edward Stafford, and Oscar P. Hampton, Jr., Chairman. The members of this Subcommittee are not in full agreement on some of the details discussed herein, but they are in full agreement on the principles involved.

7. The production of tetanus toxin within the tissues following a wound in an actively immunized person probably stimulates a rise in titer of antibodies, yet the rise may not be rapid enough to provide protection; hence, routine booster injections every 2 to 4 years and a "wound booster" are advised.

8. Penicillin and broad spectrum antibiotics initiated promptly after injury are probably powerful deterrents against tetanus infection, especially for a brief period. Tetanus is a toxemia and not an invasive infection. Even so, available evidence shows that antibiotics given early are valuable in preventing the infection. Antibiotics should not be used as a substitute for active or passive immunization.

9. In the great majority of instances, local signs of tetanus precede systemic signs. Therefore, every patient with a severe wound, whether he is immunized passively or actively, should be watched closely for several weeks.

10. Studies indicate that persons who have once had basic immunization with tetanus toxoid may have an adequate level of protection recalled by a booster dose no matter how many years have elapsed since the course of basic immunization or the last booster dose.

11. The Board of Regents and the Committee on Trauma of the American College of Surgeons recommend that mass immunization with tetanus toxoid be a part of every program for civil defense.

B. BASIC IMMUNIZATION

1. Primary active immunity is obtained by giving 3 doses of the alum-precipitated toxoid subcutaneously. The second dose is given 1 month after the first; the third dose, 6 to 12 months later. Periodic booster doses are then given normally at intervals of 4 years.

2. Infants and children up to 4 years of age receive tetanus toxoid in combination with diphtheria toxoid and pertussis vaccine. This is given at monthly intervals for 3 doses, with a fourth dose 1 year later. Children 4 to 11 years of age are given the tetanus-diphtheria toxoids. (These combinations are used for booster doses as well as basic immunization.)

3. Some patients are likely to incur tetanus prone wounds. The physician should regard these patients as in particular need of highly effective tetanus immunization, including the maintenance of an adequate antitoxin level for the control of unrecognized infections. Four doses of toxoid in the primary immunization schedule and periodic booster doses at intervals of 2 years will provide the necessary protection.

C. PROPHYLAXIS AGAINST TETANUS IN WOUND MANAGEMENT

1. Patients Actively Immunized with Toxoid

a. To patients who have had their basic immunization or a booster dose of tetanus toxoid within 4 years, give 0.5 ml. of alum-precipitated or fluid toxoid subcutaneously.

b. For patients who have had basic immunization but have not had a booster dose within 4 years of the time of a wound a booster dose of toxoid is all that is usually required. However, when the character of the wound indicates an overwhelming possibility of tetanus infection, additional protection should be given, particularly for the first few days, provided the patient is not sensitive to horse serum. Five thousand units of tetanus antitoxin are given in one arm, while, with a separate syringe and needle, 0.5 ml. of *alum-precipitated* tetanus toxoid is given in the other arm as a wound booster.

2. Patients Not Previously Immunized with Toxoid

a. In patients with clean minor wounds for which passive immunization is not provided active immunization with alum-precipitated toxoid should be initiated. This opportunity to start active immunization should not be wasted.

b. To patients who have never been immunized with toxoid, but in whom the character of the wound indicates the need for tetanus prophylaxis, give 5000 units of tetanus antitoxin (see Determination of Sensitivity to Equine or Bovine Serum, Section VI, C, 3 of this chapter). At the same time, initiate active immunity against tetanus by giving 0.5 ml. of the alum-precipitated tetanus toxoid in a different extremity with a separate syringe and needle. Urge the patient to complete the series of injections in order to obtain active immunization.

c. In patients sensitive to horse serum, that is, with a history of sensitivity to horse dander or serum, or positive skin and eye tests (see VI, C, 3), a history should be taken carefully to elicit possibility of sensitivity to beef products, and tests for sensitivity to bovine tetanus antitoxin should be carried out. If the patient is found not sensitive to bovine serum, give 5000 units of bovine antitoxin.

d. If the patient has a history of positive or suspect sensitivity, or has positive or suspect sensitivity tests, administer 0.1 ml. of 1:10 dilution of antitoxin subcutaneously, having epinephrine in a syringe, ready to use, at hand. If no significant reaction is observed in 30 minutes, administer 0.1 ml. of undiluted antitoxin subcutaneously If no reaction of significance occurs during the following 30 minutes, the remainder of the dose may be given subcutaneously or intramuscularly.

e. If there is a clear-cut history of severe reactions to both equine and bovine serum, or if a reaction occurs with the tolerance test outlined in (d) above, do not give antitoxin. Human hyperimmune globulin may be given if available; if it is not, in urgent cases consideration is given to the use of transfused blood from a donor who has received a booster dose of tetanus toxoid one month previously. Insure adequate debridement of the wounds, and leave them open. Give penicillin or tetracycline derivatives promptly in large doses for the estimated incubation period of tetanus, which is a minimum of 10 days. In all instances, start basic, active immunization with alum-precipitated tetanus toxoid.

3. Determination of Sensitivity to Equine or Bovine Serum.
Prior to the administration of any animal serum, all patients should be carefully examined for possible sensitivity to the serum. Such examination includes:

a. *History.* Question the patient carefully concerning allergic conditions, especially asthma, eczema, or urticaria, past or present. Previous injections of horse serum or other serums of any kind may be significant, particularly if a reaction ensued. Sensitivity frequently develops after the first injection of animal serum. A known sensitivity to horse dander is a danger signal, as is sensitivity to beef products.

b. *Skin tests.* Intracutaneously inject 0.02 ml. to 0.03 ml of a 1:10 saline dilution of tetanus antitoxin. The area of infiltration should be about the size of the head of a pin. A positive reaction in 15 minutes or less, manifested by a hive-like wheal and erythema, indicates sensitivity to the horse serum. The larger the wheal, the greater the sensitivity. A wheal up to 0.5 cm. in diameter (approximate size of the rubber end of a pencil) may be a nonspecific positive reaction which may be confirmed by a control skin test with normal saline. If the control test appears the same as the serum test, the reaction with tetanus antitoxin may be considered negative.

c. *Eye tests.* Place a drop of 1:10 dilution of tetanus antitoxin in the conjunctival sac of one eye at the time the skin test is made. Redness of the conjunctiva, occurring in 5 or 10 minutes, indicates a positive reaction. If the test with 1:10 dilution is negative and the skin test is positive, the eye test should be repeated with the concentrated tetanus antitoxin. After the result is apparent, a drop or two of epinephrine, 1:1000, should be instilled into the test eye.

REFERENCE

1. Committee on Trauma, American College of Surgeons. The Early Care of Soft Tissue Injuries, pp. 22–25, W. B. Saunders Company, Philadelphia, 1960. (In the combined volume, The Management of Fractures and Soft Tissue Injuries, pp. 164–168.)

SYNTHETIC SKIN: AN EXPERIMENTAL STUDY

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The treatment of massive burn injuries remains a challenge. The toll formerly taken early by "shock" is nowadays exacted at a later stage by infection; the ultimate mortality has been reduced but little, if at all. Further gains must be sought in the management of the burn wound, the basic surgical objective being the excision of necrotic tissue, appropriately timed, and closure of the wound. However, if the area of destroyed skin exceeds that remaining available as a donor site for autografting, this goal becomes difficult and often impossible to reach. Homografts, heterografts, as well as fetal membranes have been used as skin replacements but in general, have failed to provide more than a very temporary and precarious covering.

The potential value of an inert skin prosthesis, if proper adherence can be secured, is obvious. Availability in unlimited quantity and dimension, absence of storage problems, impermeability, and the lack of need for blood supply should indeed be significant advantages. Sheets of "Ivalon Surgical Sponge" with and without an outer layer of silicone rubber have been evaluated for this purpose and the results of these preliminary experiments form the basis for this report.

Synthetic materials have found increasing acceptance as tissue replacements in a number of applications and one of the most extensively employed substances is the Ivalon Sponge, a polymer produced by formalinization of polyvinyl alcohol. Rigid when dry, the material becomes soft, pliable and elastic when it is moist. The pores of the sponge are in continuity with each other. Embedded into living tissue, it is rapidly permeated by an actively proliferating granulation tissue which, as time goes by, tends to become increasingly fibrous. If left in situ for any length of time, its desirable initial structural characteristics tend to be lost but this is of no concern in this application since only a temporary prosthesis is contemplated. The degree of tissue growth into the sponge depends largely upon pore size and the latter can be regulated by compression applied to the material during autoclaving (1, 2).

It was thought that if a sheet of this material were firmly sutured in place on a denuded surface of body tissue, adherence might be secured by growth of granulation tissue into the sponge. To prevent loss of body fluids, the outer surface of the sheet was rendered impervious to water by a coat of silicone rubber. From

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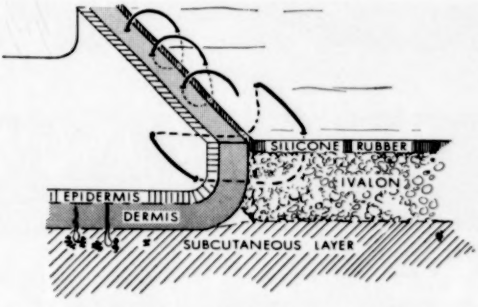

FIG. 1. Schematic drawing of interrupted everting mattress suture reinforced by a continuous running stitch.

a variety of these materials, "Silastic RTV-502" and "Silastic Q-3-0149"[1] were selected because they are known to be non-irritating to tissues, vulcanize at room temperature, and therefore, are easy to work with in the laboratory. The material is merely spread onto the surface of the Ivalon sheet and after setting, it adheres firmly to the pores of the latter. The sheet can be sterilized by boiling or autoclaving.

METHODS

Twenty-eight skin defects (varying in size from 2″ × 2″ to 6″ × 12″) were produced in 16 mongrel dogs and were covered with similar sized prostheses. All experiments are included in this account with the exception of one animal which was too hard to handle and was taken out of the series after a few days. Suitable areas, usually on the lateral surface of the chest wall, were prepared by shaving and the application of a depilatory agent. After disinfection, the skin was excised down to subcutaneous tissue and a prosthetic patch was sutured in place. Several suture techniques were tried. These included an end-to-end butt joint, an overlap of the patch onto the surrounding skin, and an overlapping of an undermined skin margin onto the Ivalon sheet. None of these were satisfactory but the resulting failures are included in the tabulation of results. The epithelium, constantly renewing itself, was the principal obstacle and if permitted to grow underneath the patch before firm granulations had penetrated into the Ivalon, it would lead to elevation and infection of the margin of the patch.

An everting interrupted mattress suture, reinforced by a continuous running stitch proved to be most satisfactory (Fig. 1). With this technique, it took some time for the epithelium to reach the line where Ivalon and subdermal tissue met. By then, tissue ingrowth had taken place and a junction with only minimal crust formation and drainage could be established.

Animals were placed on penicillin (300,000 units) and streptomycin (0.5 grams) daily for eight to ten days. They were muzzled and a bandage was applied around

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[1] Dow-Corning Company, Midland, Michigan.

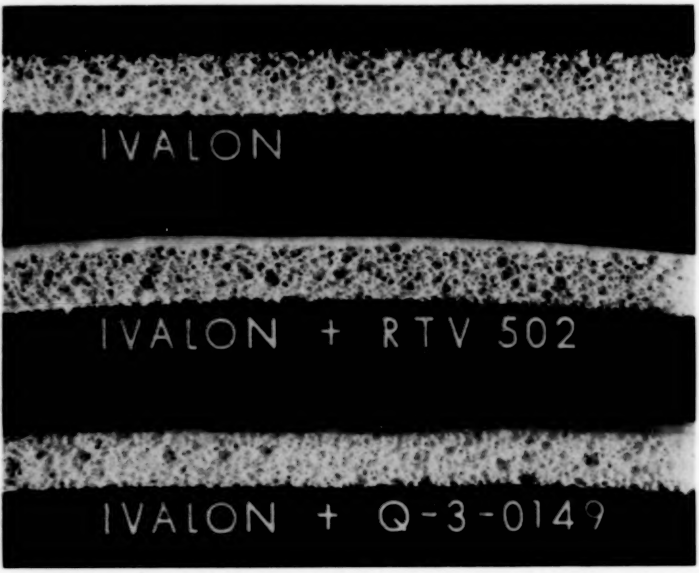


FIG. 2. Photograph of cross sections of the three types of prosthesis used in these experiments.

the thorax. Nevertheless, a number of animals got at their patches and some were lost in this fashion. Dressings were changed daily and biopsies and cultures taken at suitable intervals.

No effort was made to gradually replace the inert covering, either by autografts or by progressive circumferential trimming. The objective of this experiment was merely to study adherence and behavior of the patch as time went by without dealing with the problem of ultimate replacement of the prosthesis by the animal's own skin.

The following three types of covering were used (Fig. 2):

Type A—Sheet of Ivalon alone, 0.5 to 1.0 cms. thick.

Type B—Sheet of Ivalon, same thickness, covered by a 1 millimeter coat of Silastic RTV-502.

Type C—Sheet of Ivalon, same thickness, with a 1 millimeter coat of Silastic Q-3-0149.

RESULTS

Table I summarizes the results with 28 prostheses. In three-fourths of the experiments, a take was achieved. This tabulation includes all initial trial methods and if one excludes the four experiments which, in the light of subsequent knowledge can be considered as never having had a chance to succeed, 24 patches are left of which only four failed to take. The observations made on the behavior of these three types of prostheses can be summarized as follows:

(1) *Ivalon covered with Silastic RTV-502 (Type B).* There were nine patches in this group which turned out to be the least successful. The outer silicone layer was too rigid and brittle. It tore easily when sutured and it was impossible to produce a tight junction with the surrounding skin (Fig. 3). Infection would occur at the skin margin and then extend beneath the silicone covering into the layer of pores which had not yet been penetrated by granulation tissue. Of the nine prostheses, three were out and out failures due to massive infection and spontaneous loosening—on days 7, 16 and 17 following application. In the remaining six prostheses, infection did ultimately occur but it did not interfere with adherence to underlying tissue and it was sufficient to remove the outer silicone layer in order to salvage the patch. In two of these instances, the prosthesis was in place for 20 and in one instance for 23 days before the surface layer had to be removed. Thereafter, the remaining Ivalon sheet exhibited a behavior entirely similar to those prostheses in which Ivalon alone was used initially, and the course of these will be described below.

TABLE I

Tabulation of Results with 28 Synthetic Patches

Failures		7
Infected and loose.		
(Lost on days 7, 9, 14, 16, 17, 19, 20)		
Successful Takes		21
a. Bitten off by dog	9	
(On days 7, 9, 10, 12, 17, 17, 28, 34, 41)		
b. Excised (planned biopsy)	12	
(On days 23, 32, 34, 40, 40, 40, 40, 60, 60, 60, 75, 104)		

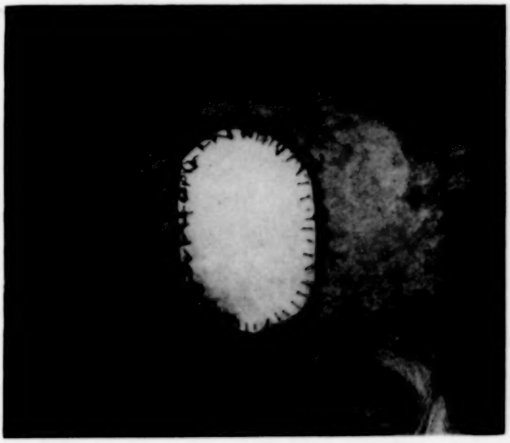


FIG. 3. Photograph of Type B prosthesis (Ivalon covered with Silastic RTV-502) five days after application.

In summary, with this particular combination of materials, adherence was secured in six out of nine experiments but infection could not be prevented for periods in excess of approximately 20 days. The predominant bacterial contaminants were Pseudomonas pyocyaneous, Pseudomonas species, Proteus mirabilis, Proteus morganii, and beta Enterococci.

(2) In ten experiments, *an Ivalon sheet covered by Silastic Q-3-0149 (Type C)* was used (Fig. 4). The characteristics of this material are by far better suited for this application. It is soft, pliable, elastic and easy to suture. This silicone rubber is somewhat transparent and before vulcanizing, it has a buttery consistency. It cures by exposure to moisture in the air and some setting occurs after 30 minutes. It is possible to puncture or incise the impervious layer for as-

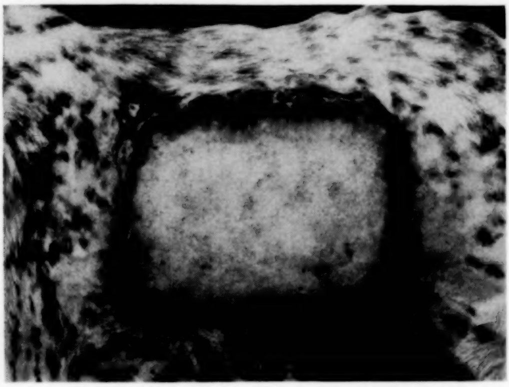


FIG. 4. Photograph of Type C prosthesis (Ivalon covered with Silastic Q-3-0149) seven days after application. (Suture line had been sealed with a thin layer of Silastic, the remnants of which can still be seen.)

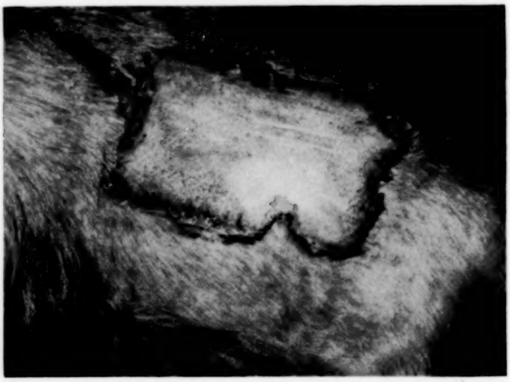


FIG. 5. Photograph of Type C prosthesis (Ivalon covered by Silastic Q-3-0149) 17 days after application.

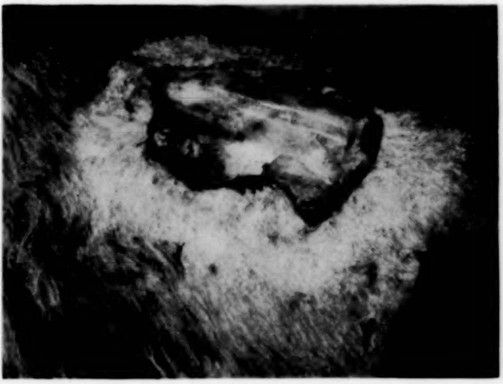


FIG. 6. Photograph of prosthesis shown in Figure 5 but 30 days after application. Elevation and contraction of the wound are beginning to occur and some slight trimming of the margin has been necessary. Adherence has remained firm.

piration or biopsy and then seal the break by application of the silicone rubber paste.

Also, this Silastic exhibits some adhesion to dry skin and after the prosthesis is in place, the suture line can be sealed by a thin layer of Silastic. This seal, while obviously only temporary, is nevertheless adequate for 24 to 48 hours (Fig. 4). By then, some adherence has occurred and after a week or so, a tight junction can be observed, with only a small crevice remaining between synthetic cover and surrounding skin.

In this group of ten, only one patch loosened spontaneously. In two instances, infection occurred underneath the silicone layer, which had to be removed on the 12th and 17th days respectively but the underlying Ivalon layer remained adherent. Of the remaining seven successful patches, some were bitten off by the animals but it was possible to maintain two patches for 34 days and three for 40 days. After three weeks, contraction of the whole wound could be observed and between the 30th and 40th day, some elevation and buckling of the prosthesis was seen but separation of the patch from the underlying connective tissue did not occur. Since reduction in size of the patch was not part of this study, an excisional biopsy was then performed. Figures 5 and 6 depict this type of patch at 17 and 30 days after application. Figures 7 and 8 illustrate a specimen of such a prosthesis excised in toto after 40 days.

In summary, the results with this combination of materials (Ivalon covered with Silastic Q-3-0149) were encouraging. Loosening occurred only in one out of ten instances and prostheses with their surface covering intact could be carried up to 40 days.

(3) The third group (*Type A*) *consisted of Ivalon sheets without any surface covering.* Nine of these were applied primarily in this form but an additional eight prostheses should be added to this group. These originally had consisted of Ivalon covered with a layer of "Silastic" which subsequently had to be re-

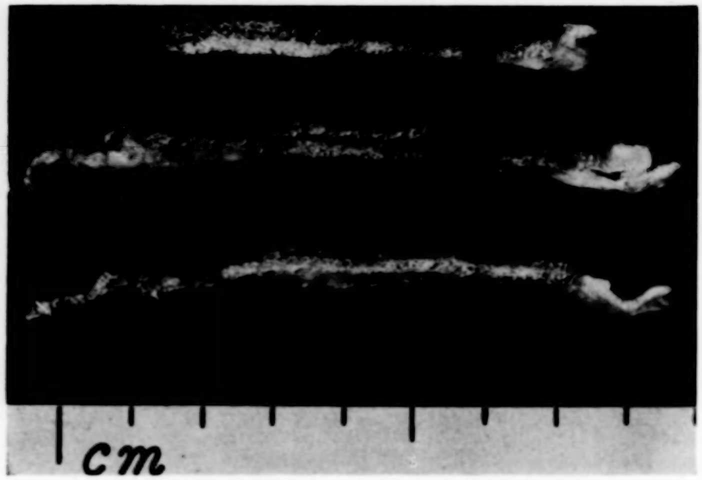


Fig. 7. Photograph of three sections through a type "C" prosthesis excised in toto with surrounding tissues 40 days after application. Firm adherence at base and margins is evident.

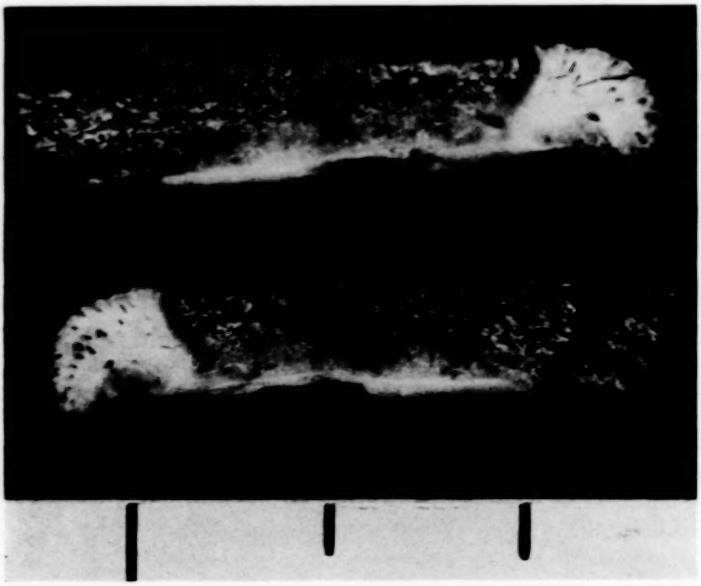


Fig. 8. Enlarged photograph of sections of junctional area between normal skin and Type C prosthesis. Firm connective tissue is seen to penetrate into the base and into the margins of the Ivalon sponge. The distance between marks at the bottom measures 1 centimeter. Note that the depth of the crevice, well seen on the upper specimen, measures 2 millimeters at the most.

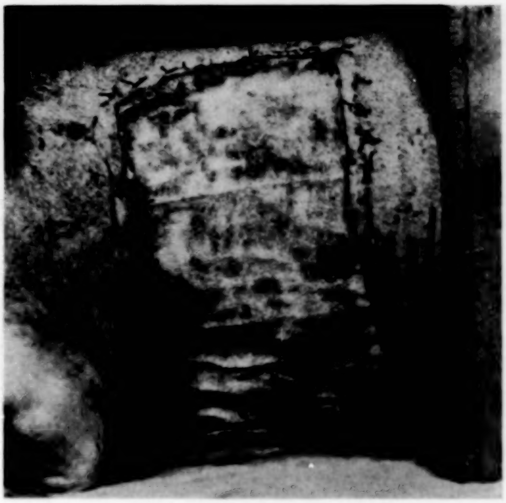


FIG. 9. Photograph of Type A prosthesis (Plain Ivalon Sheet) ten days after application.

moved. (Six from Group 1 and two from Group 2.) The behavior of these prostheses was essentially the same and they will therefore, be evaluated together. Since the surface of the Ivalon sponge by itself is not impervious, some serous drainage would, of necessity, occur. However, adherence was very easily procured and after approximately five to seven days, a firm junction between the surrounding tissue and the Ivalon could be noted. To reduce surface infection, a number of antiseptic solutions were applied topically at the change of dressing. Two percent (2%) molar monochloracetic acid, boric acid, neomycin, and bacitracin solutions were employed.

The most noteworthy feature of this type of prosthesis, was the fact that after a week or ten days, it was possible to let the surface of the Ivalon sheet dry. This produced a fairly rigid plaque with hardly any drainage at all and extremely firm adherence to surrounding tissues (Fig. 9). Later on in the course, one quite often would see infection and suppuration, but nearly always this was restricted to a small and limited area of the prosthesis. It was then only necessary to moisten the Ivalon with one of the aforementioned solutions and the suppuration would clear. The base of the patch remained adherent throughout and it was possible to again dry the surface. At the margin of the patch, one could see epithelium grow onto the granulation tissue which had come up through the Ivalon pores. This margin of epithelium would extend for about 0.5 to 1.0 centimeters onto the surface of the prosthesis (Fig. 10). In some instances, the thickness of the Ivalon was too great and the excess was shaved off. If too deep a cut was made, bleeding granulation tissue was encountered within the pores of the Ivalon.

Most of the prostheses were completely unchanged after the second or third week and were removed after six to eight weeks although two were carried for

75 and 104 days respectively. No change was noted after this length of time and the margin of surrounding epithelium did not seem to advance any further towards the center of the patch (Fig. 10).

The significant finding in these 17 experiments was that adherence was easily secured with a covering consisting solely of Ivalon. Only three out of 17 applications were complete failures. After penetration of the pores of the sponge by the underlying connective tissue, the surface of the latter could be dried out. Occasional infection did occur but did not present an insurmountable problem. In fact, drainage was minimal if compared to the large amount of pus saturating a dressing applied over any raw granulating wound.

DISCUSSION

We believe that it is warranted to conclude from the foregoing experiments that a sheet of Ivalon used to close a skin defect will be permeated by granulation tissue arising from the underlying subcutaneous layer (Figs. 11 and 12). The sheet then becomes adherent to the base of the defect as well as to the surrounding margin of normal skin. Although this series is small, it supports the conclusion that this layer can be made water-tight as long as 40 days by covering the Ivalon with an impervious layer of silicone rubber. When Ivalon is used alone, the results

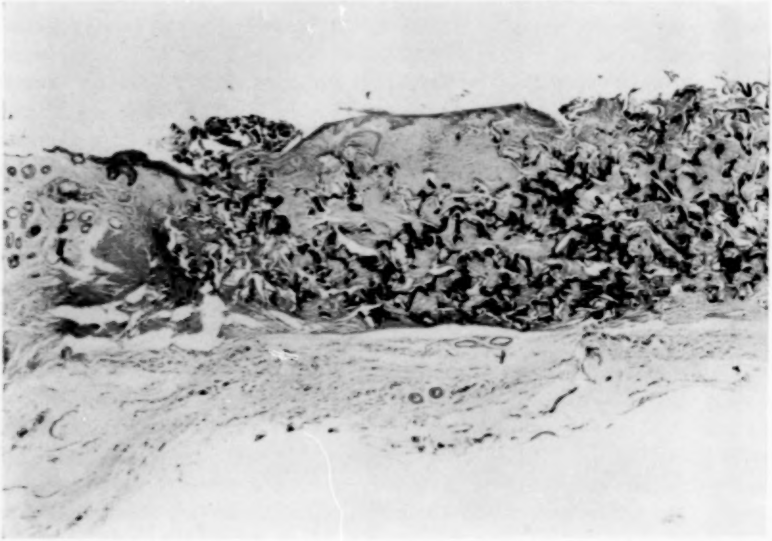


FIG. 10. Microscopic appearance of Type A prosthesis (Plain Ivalon) excised 104 days after application. The field shown covers the junction with surrounding skin, the latter being discernible at the left. Creeping squamous epithelium extends from the normal skin margin onto the surface of the prosthesis. Underneath it, there is considerable consolidation of the connective tissue. The Ivalon exhibits features of aging, fragmentation and calcium deposits. The slit-like space below the prosthesis is an artefact. (Magnified 17 times.)

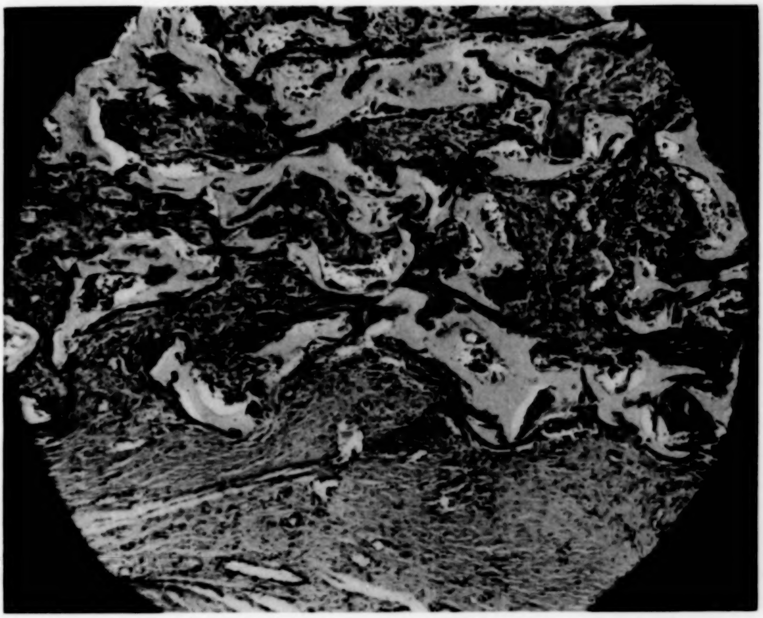


FIG. 11. Microscopic appearance of junction between subcutaneous tissue (lower half of field) and undersurface of Type B prosthesis, ten days after application. Fairly vascular granulation tissue is seen to extend into several layers of pores. (Magnified 74 times.)

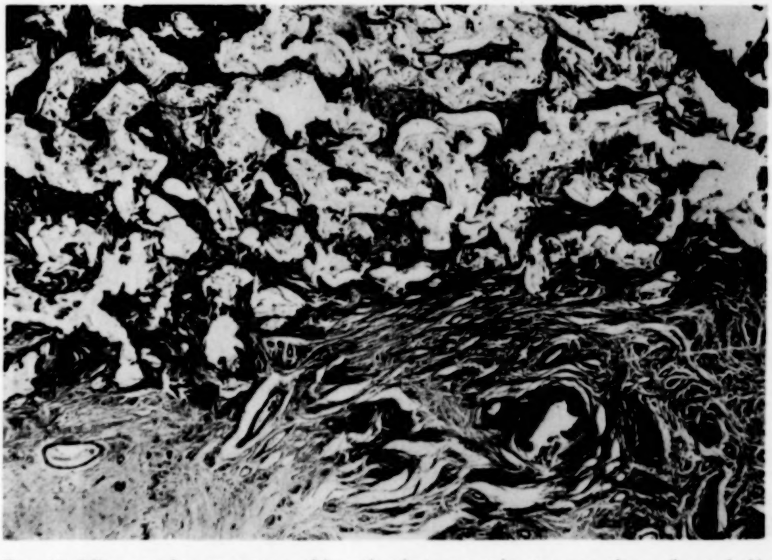


FIG. 12. Microscopic appearance of junction between subcutaneous tissue (lower half of field) and undersurface of Type C prosthesis 34 days after application. (Magnified 25 times.)

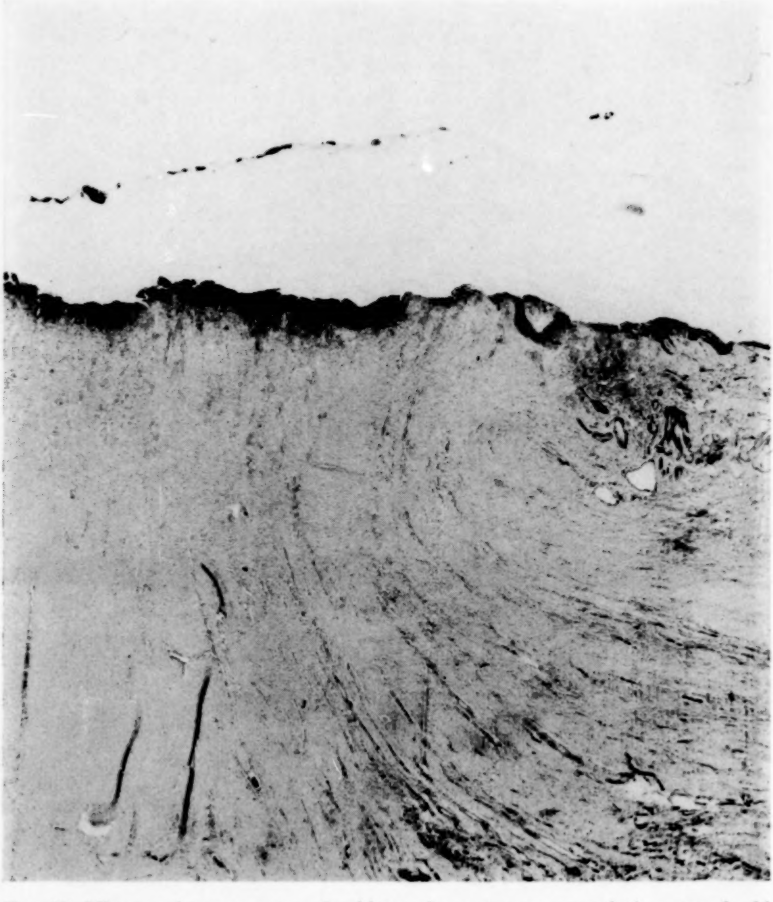


FIG. 13. Microscopic appearance of a biopsy from an open granulating wound which had resulted from the removal of a skin prosthesis two weeks earlier. The epithelium is seen to terminate at the right half of the field. The remainder of the surface is covered by debris above a zone of inflammatory response. Dense connective tissue is seen in the deep layers. (Magnified 17 times.)

have been somewhat better in terms of the length of time for which it is possible to maintain these prostheses in place. When the surface of such an Ivalon sheet is dried, the prosthesis becomes rigid. This may not be desirable but, on the other hand, the minimal drainage under those circumstances was impressive.

It seemed of interest to know whether this type of skin prosthesis could be made to adhere to a pre-existing layer of granulation tissue with its implied surface infection. In three experiments (included in the account of Group 3), after

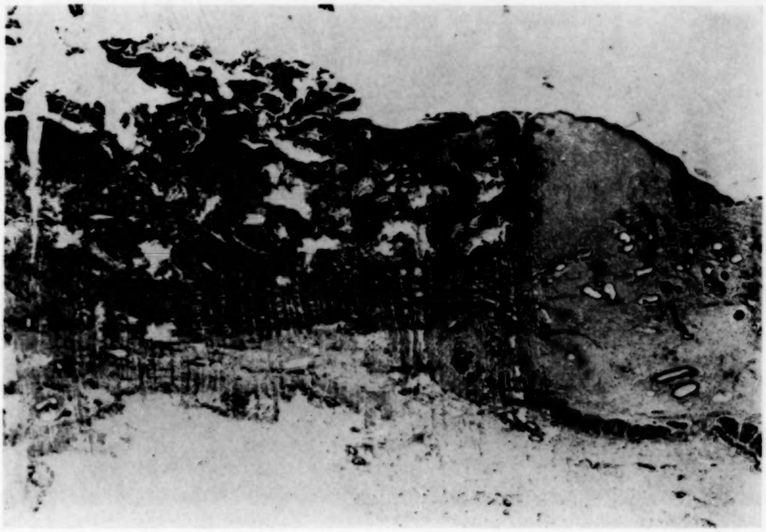
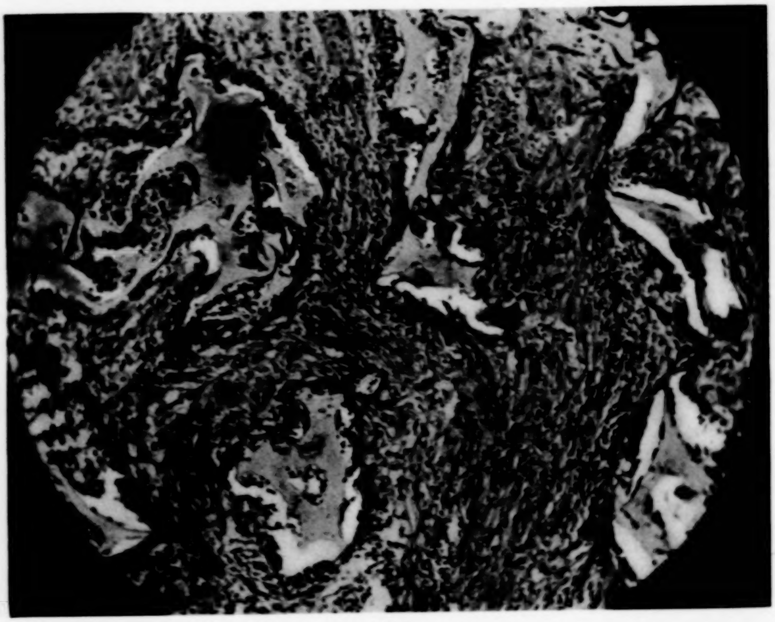


FIG. 14. Microscopic appearance of an Ivalon prosthesis four weeks after application on infected granulation tissue. (Shown in Figure 13.) The prosthesis has become well anchored and there is abundant ingrowth of loose granulation tissue into the Ivalon pores. An advancing margin of epithelium can be seen to extend from normal skin (right side of field) onto the surface of the prosthesis. (Magnified 17 times.)

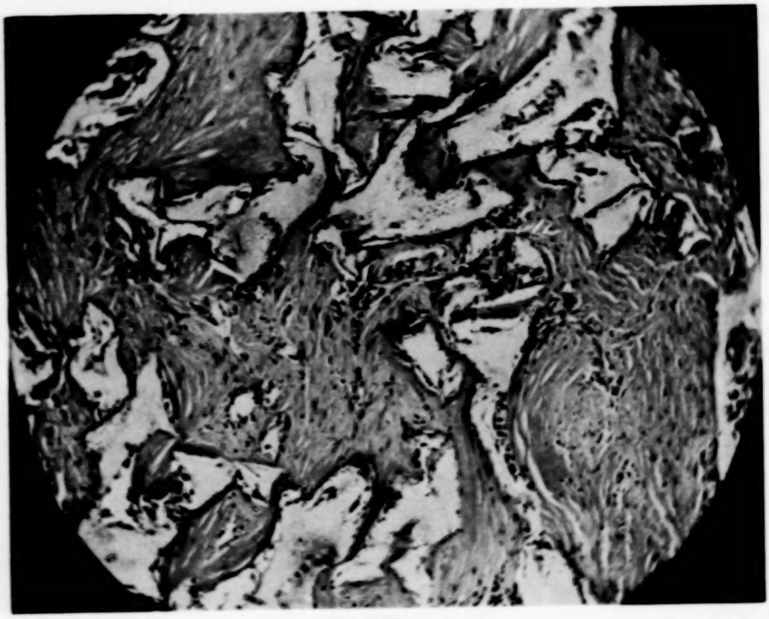
excisional biopsy of a skin prosthesis, the resultant wound was left open and permitted to granulate. After two weeks, the skin margin was freed without disturbing the granulating surface and a plain Ivalon covering was applied. Adherence was secured in these three instances (Figs. 13 and 14) but this finding needs to be substantiated further in a larger series.

An incidental observation made in the course of this study deserves recording. During the early phase of the experiments we were unaware of the fact that firm adherence of the prosthesis could be obtained within a few days, and various means of accelerating tissue growth into the Ivalon sponge were considered. Robertson and Schwartz (3) in 1953 had observed that an active granuloma, rich in collagen, occurs at the site of injection of Carrageenin into the subcutaneous tissue of a guinea pig. This material, extracted from Irish moss (Chondrus Crispus), is a sulfated polygalactose and has been widely used in the study of connective tissue metabolism. In seven of the prostheses listed above (Type B and C), the Ivalon was impregnated with a colloidal solution or a gel of Carrageenin with or without added antibiotics.[2] The hoped for initial acceleration of tissue ingrowth was not borne out but a remarkable difference in the microscopic ap-

[2] Carrageenin extracts, Seakem 21 and Gelcarin 500, were used. Courtesy of Marine Colloid, Inc., New Bedford, Massachusetts.



15A



15B

Figs. 15A and 15B. Microscopic appearances of two skin prostheses of the same age and in the same animal. *A*. Highly cellular connective tissue filling the pores of the Ivalon, 24 days after application. (Magnification 120 times.) *B*. Solid and relatively acellular connective tissue with intense collagen deposition in the pores of the same type of prosthesis impregnated with Carrageenin, 24 days after application. (Magnification 120 times.)

pearance of the tissue in the Carrageenin-containing Ivalon was observed in comparison with the granuloma which occurred with Ivalon alone.[3] In the presence of Carrageenin extracts, there is a remarkable deposition of collagen and the tissue is relatively acellular. This is well demonstrated in Figures 15-A and 15-B.

Recently, McCandless, et al. (4, 5), have observed that the morphology of the Carrageenin-induced granuloma can be modified by feeding cholesterol to the recipient animal (rabbit). Numerous fat-filled foam cells can be seen in such tissue. More importantly, some morphological change can be induced by merely incorporating the cholesterol into the injected Carrageenin extract. Since this observation implies that it is possible to manipulate the character of this connective tissue by a locally applied agent, it might perhaps be possible, with a suitable combination, to stimulate growth of a tissue with characteristics such that it would form an optimal base for the autograft which ultimately must replace the skin prosthesis.

It should be emphasized that these preliminary experiments were carried out under unfavorable conditions, that is, on a furry animal, difficult to keep clean, and with the prosthesis kept under a tight bandage under which some moisture is of necessity present, a set of circumstances which clearly favors infection.

The structural and chemical properties of the materials used in this study are also factors of obvious importance in the evaluation of the results. For instance, the thickness and the pore size of the Ivalon were arbitrarily chosen and may not be at all optimal for this purpose. Furthermore, it is now possible to produce porous silicone rubber sheets[4] and it might well be that tissue growth into these materials can be obtained without the considerable scarring reaction seen with the use of Ivalon alone.

An evaluation of various synthetic materials suitable for this application, as well as a study of the problem of the ultimate replacement of the prosthesis by autografting need to be made. Also, one needs to know whether the results obtained after excision of normal skin can be duplicated following the debridement of experimentally induced burn wounds. To answer some of these questions, experiments are currently being carried out in our laboratory on pigs whose skin bears a fairly close resemblance to the human integument.

CONCLUSIONS

1. Areas of skin varying from 2″ × 2″ to 6″ × 12″ in size were removed from dogs. The defects were closed by similar sized sheets of either Ivalon alone or Ivalon covered with silicone rubber providing an outer impervious layer.

2. Adherence of such patches to the animal's subcutaneous tissue and surrounding skin was obtained in three out of four experiments and in five out of six, if some of the initial and inherently faulty trial experiments are omitted from consideration.

[3] A detailed account of the histological and bacteriological observations made when various combinations of Carrageenin extracts and antibiotics were used as fillers in the pores are beyond the scope of this presentation and will be reported separately.

[4] Dow-Corning Institute of Medical Research, Midland, Michigan.

3. Ivalon sheets made impervious by silicone rubber were maintained in place for periods up to 40 days. Sheets of Ivalon alone have been carried as long as 104 days.

4. Adherence could be secured if Ivalon sheets without a covering were applied over infected granulation tissue.

5. A method of manipulating the character of the granulation tissue in the pores has been briefly mentioned.

6. These preliminary experiments were limited to three types of prostheses. Other materials or combinations of materials may be found to be better suited for this purpose.

7. The problems of the ultimate replacement of the prosthesis by the animal's own skin as well as that of extending this technique to the coverage of wounds resulting from experimental burns are now under investigation and will be reported upon separately.

REFERENCES

1. Merendino, K. A., Blumberg, J. B. and Griffith, P. C. The effect of Specific Compression on Soft Tissue Response to Formalized Polyvinyl Alcohol (Ivalon) Sponge: A Critical Evaluation. Ann. Surg., **151:** 409–418, 1960.
2. Adler, R. H. and Darby, C. Basic Considerations in the Use of a Porous Synthetic Sponge (Ivalon) in Surgery. In print, Armed Forces Med. J.
3. Robertson, W. Van B. and Schwartz, B. Ascorbic Acid in the Formation of Collagen. J. Biol. Chem., **201:** 689, 1953.
4. McCandless, E. L., Bailey, R. E. and Zilversmit, D. B. Influence of Cholesterol Feeding on Phospholipid Metabolism of Connective Tissue. Circulation Research, **8:** 724–729, 1960.
5. McCandless, E. L. Personal Communication. Chronic Disease Research Institute, University of Buffalo, Buffalo, New York.

COMPLEX FRACTURE OF THE LATERAL MALLEOLUS

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Fractures of the ankle are readily visualized in x-ray films and when both malleoli are broken the instability of the ankle mortise is obvious. The soft part concomitants of ankle injuries are more obscure but produce equal instability. The purpose of this paper is to emphasize that a ruptured deltoid ligament may pass unrecognized with disastrous results if the surgeon allows his attention to remain distracted by what appears in the x-ray film to be an isolated fracture of the fibular malleolus.

Fracture of the fibular malleolus is a minor injury only when the talus remains stabilized by an intact deltoid ligament on the other side of the joint. When this ligament is also ruptured, the ankle mortise is unstable and a silent displacement of the talus may persist or recur within the best of immobilizing dressings. Failure to recognize and correct even a small amount of talar displacement almost always eventuates in a painful and crippling disability.

An intact deltoid ligament does not allow the talus to displace from the medial malleolus more than 3 mm. Displacement in excess of 3 mm. consistently has been associated with a complete rupture of this ligament. The significance of a failure to recognize this anatomical fact is illustrated by the following example.

This ankle (Fig. 1), following a skiing injury, was diagnosed and treated as an isolated fracture of the lateral malleolus despite pathognomonic x-ray evidence of a deltoid ligament rupture. Three successive manipulative reductions failed and a consulting specialist was called. He performed open reduction of the fracture, but the talus remained displaced. Three months later, another surgeon osteotomized the fibula and fixed the lower fragment to the tibia. The talus remained displaced. Eight months after injury, the deltoid ligament tear finally was recognized and a third surgeon extricated the ligament from between the talus and medial malleolus where it had remained incarcerated since the moment of injury to block all attempts at reduction. The end result was satisfactory, but this apparently innocuous injury would have eventuated in arthrodesis if the true nature of the pathology had not finally been recognized and corrected.

This prototype of a situation in which a ruptured deltoid ligament escaped notice for variable periods and in which late operative reconstruction had to be done was encountered with sufficient frequency to prompt a study of our experiences with this injury. Between 1950 and 1959, four hundred and ninety ankle fractures were treated in this clinic. Thirty-three (6.7 per cent), were fractures of the lateral malleolus associated with a rupture of the deltoid ligament.

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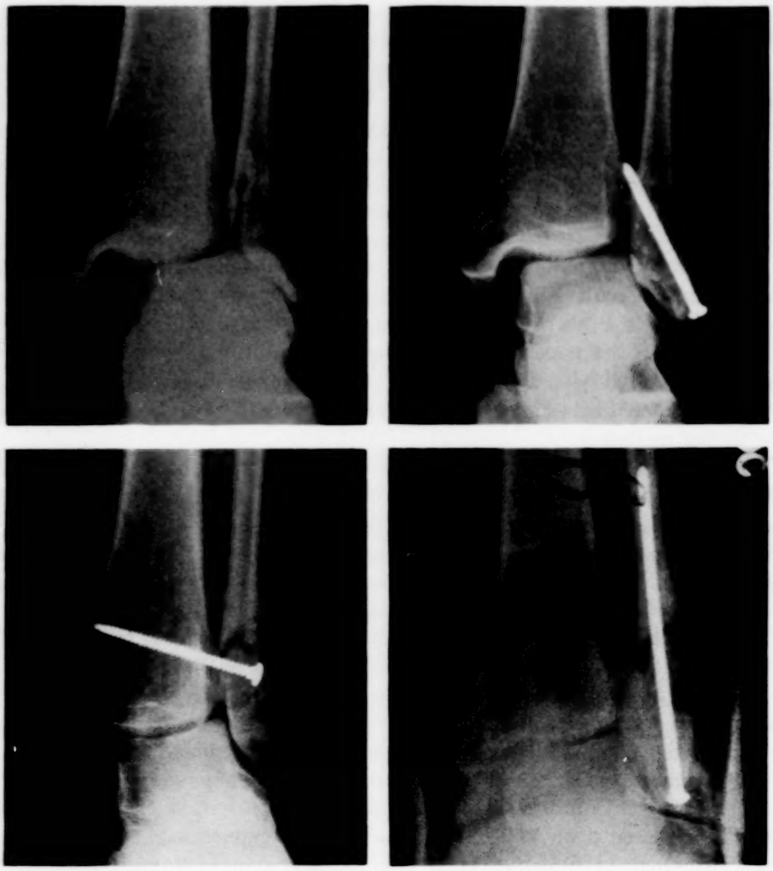

FIG. 1. *Upper left:* Rupture of the deltoid ligament is obvious. *Upper right:* Talus remains displaced after open reduction of the fracture. *Lower left:* Three months after injury, the fibula was osteotomized and the lower fragment fixed to the tibia. The talus remains displaced. *Lower right:* Eight months after injury, the nature of the injury was recognized. The ruptured ligament was removed from between talus and medial malleolus and sutured to the tibia. The fibula was osteotomized and fixed. The final result was good. (McLaughlin, H. L.; *Trauma*, W. B. Saunders, Philadelphia, 1959.)

THE DIAGNOSIS

In all thirty-three cases, there was sufficient pain, tenderness, swelling and ecchymosis under the intact medial malleolus to justify a strong clinical suspicion of deltoid ligament damage. In one-third of these cases, the amount of displacement or instability of the foot on the leg was enough to make a diagnosis of ligament rupture certain.

Anteroposterior films of a normal ankle reveal an interspace of 1 to 2 mm.

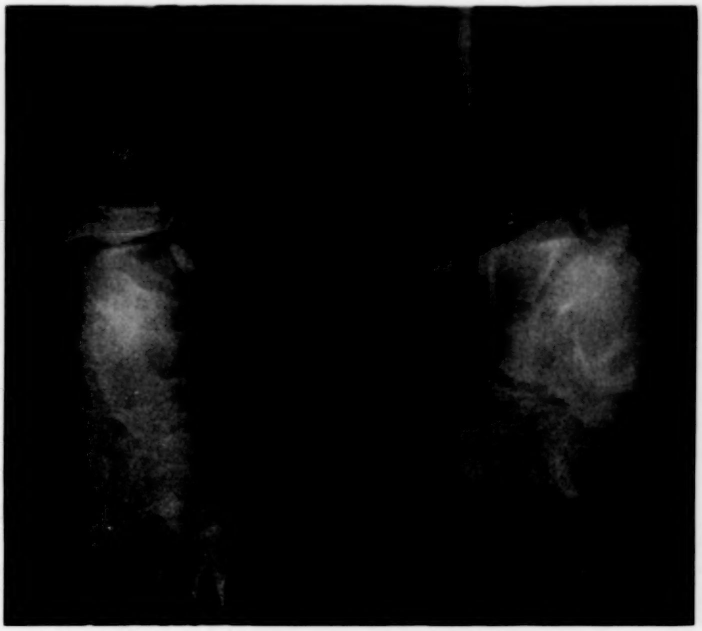

Fig. 2. *Left:* Minimal interspace of 4 mm. was found synonymous with rupture of the deltoid ligament. *Right:* Deltoid ligament rupture obvious with lateral dislocation of talus.

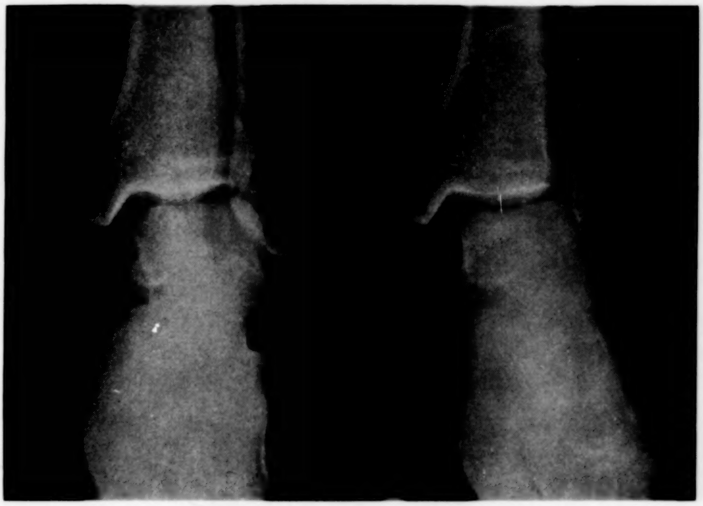

Fig. 3. 4 mm. interspace, left, doubled to 8 mm., right, when stress was applied

between the medial malleolus and the talus. In all thirty-three cases, this interspace ranged from 4 mm. upward to actual lateral or posterolateral dislocation of the talus (Fig. 2). Twenty-five of these cases were explored and all had complete ruptures of their deltoid ligaments. Only two showed a minimal interspace of 4 mm., but in each this measurement was doubled when stress films were made, (Fig. 3). The eight other cases treated without operation all had medial interspaces increased sufficiently to certify the presence of complete deltoid ligament tear. It seems clear, therefore, that any increase of the interspace between medial malleolus and talus in excess of 4 mm. constitutes reasonably certain evidence of complete rupture of the deltoid ligament.

THE MORBID ANATOMY

The level of deltoid ligament disruption was of some significance. It was avulsed from the medial malleolus in sixteen cases, and in ten of these was incarcerated between the medial malleolus and the talus constituting a mechanical block against any form of manipulative reduction, (Fig. 4). In two, the malleolus was also button-holed through over-lying fascia, and in one case through the skin. It is submitted, therefore, that unless the talus can be replaced and held in perfect apposition to the medial malleolus, incarceration of the ligament should be suspected and exploration of the medial interspace carried out without delay.

In the remaining nine cases examined at operation, the ligament was ruptured through its substance in six, (Fig. 5), and avulsed from its distal insertion in three

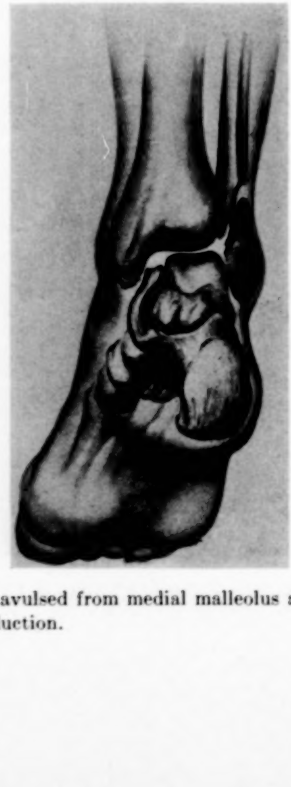

Fig. 4. Deltoid ligament avulsed from medial malleolus and incarcerated in the joint preventing manipulative reduction.

instances, (Fig. 6). In none of these cases was the ligament trapped in the joint to impede reduction. However, in the three instances of distal avulsion, the loose ligament was infolded or exfolded upon itself and superficial rather than deep to the tendon of the tibialis posticus. Interposition of this tendon between the avulsed ligament and its normal point of insertion would have precluded adequate spontaneous repair.

In eight of the cases examined at operation, chips of bone and cartilage which were not disclosed by pre-operative x-ray films were found in the joint. Whether or not or how much these chips would have accelerated or contributed to sub-

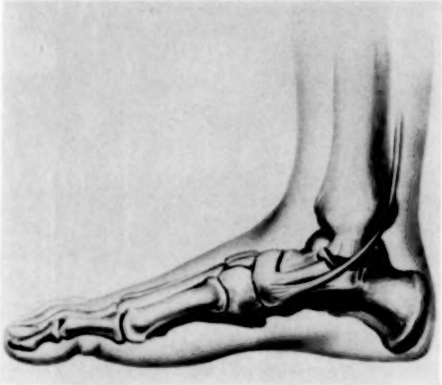

Fig. 5. Rupture of ligament through its substance. In none of these cases was the ligament trapped in the joint.

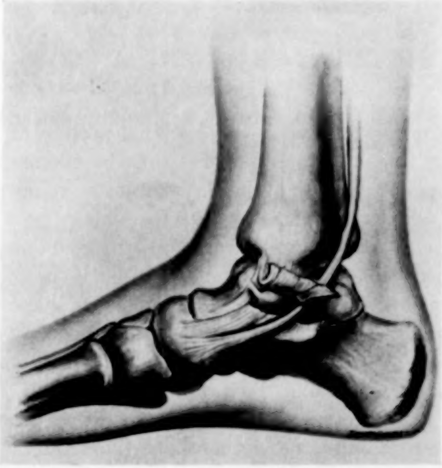

Fig. 6. Avulsion from distal insertion with exfolding of ligament and interposition of posterior tibial tendon precluded adequate spontaneous ligament repair.

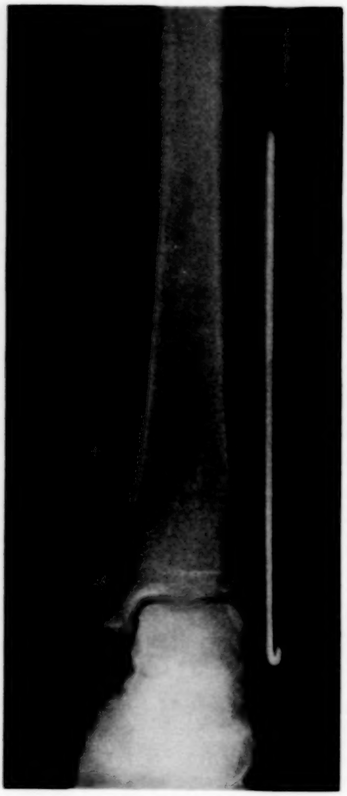

FIG. 7. Intramedullary fixation of fibular malleolus. The deltoid ligament was repaired by suture in all cases.

sequent arthritis is uncertain, but it was clear that both recognition and removal of such debris could have been accomplished only by opening the joint.

In short, more than 50 per cent of the cases subjected to operation proved to be lesions for which operative treatment was mandatory to a good result. The problem is that in only a few of these cases was this mandate recognizable until the joint was opened. It seems safe to conclude that if the talus can be replaced and held in perfect apposition to the medial malleolus, incarceration of the ruptured ligament can be excluded with reasonable certainty. However, tibialis posterior tendon interposition between the avulsed distal end of the ligament and its normal point of insertion, which was encountered in 10 per cent of cases, defied recognition or correction except by an operative procedure. The lesson would appear to be that only a perfect manipulative reduction which remains in perfect position is adequate justification for non-operative treatment, and even this tenet carries a 10 per cent risk of error.

THE MORBIDITY OF OPERATIVE TREATMENT

In the twenty-five operated cases, as an adjunct to deltoid ligament repair, the fibular malleolus was reduced and fixed, usually by some intramedullary device, (Fig. 7). Splints for seven to ten days were followed by a snug walking boot and progressive ambulation. There were no infections. The hospital stay averaged eleven days in contrast to three days for similar cases treated without operation. Return to work and full activity averaged three months whether or not operative treatment was employed. Operative treatment therefore had its calculated risks, an increased hospital stay, proved to be a necessary procedure in 50 per cent of the cases, and had little effect on convalescence. The results in both groups were consistently satisfactory.

DISCUSSION

It has been our conviction that lateral stress x-ray films should be made whenever this complex injury was suspected. This has not been substantiated. Initial widening of the interspace between the talus and the medial malleolus in excess of 4 mm. has consistently proved to be synonymous with complete rupture of the deltoid ligament, (Fig. 8). That this has been our experience does not prejudice the possibility that the talus may rest in normal position in the presence of a ruptured deltoid ligament.

Unsuccessful manipulative reduction and immobilization preceded operation in 30 per cent of the cases which came to operation. These failures of conservative treatment resulted from incarceration of the avulsed ligament in the medial interspace, from a failure to recognize the true nature of the lesion, or from faulty techniques of reduction or immobilization.

In three cases, the ligament injury remained unrecognized and the ankle distorted for five, eight and nine months respectively. These patients were crippled and eventual arthrodesis seemed inevitable. However, they were young persons and at operation the cartilage of the ankle was found to be in good condition. Repair of the neglected deltoid ligament tear, reconstruction of the malunited fibula and replacement of the talus in normal apposition with the tibia produced results which have remained excellent over follow-up periods of seven to ten years, (Fig. 9). Equally successful results have been obtained in late reconstruction of five other distorted malunions in which the medial malleolus instead of the deltoid ligament was disrupted. Old malunions of the ankle therefore do not always require arthrodesis, but are amenable to reconstruction when the articular cartilages of the joint are intact.

Fracture of the fibular malleolus associated with deltoid ligament tear, while common to many twisting injuries of the ankle, is a particularly common skiing injury. Following reduction and immobilization, the patient returns to his home surgeon for continued care, more often than not without clinical data or early x-ray films.

Unless persisting talar displacement reveals a ruptured deltoid ligament in new films, the home surgeon is in a quandary. Is the lesion a simple isolated fracture of the lateral malleolus to be immobilized for two to three weeks, or is

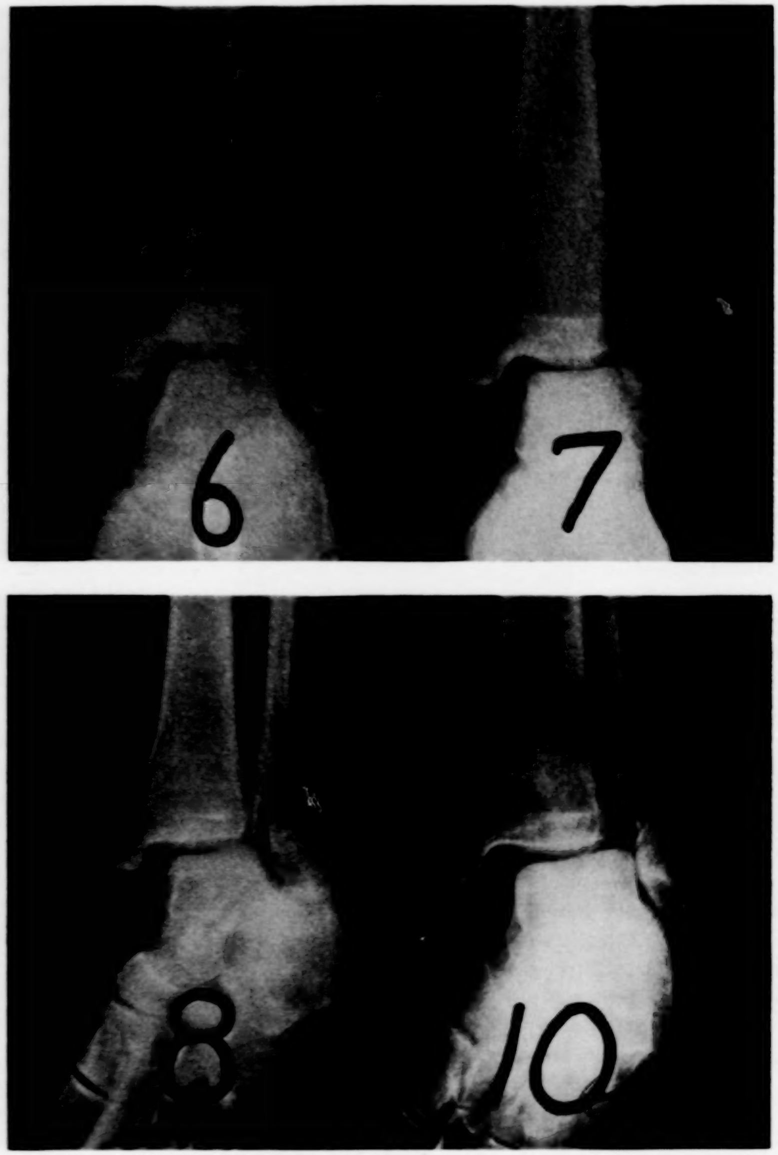

FIG. 8. Deltoid ligament rupture was consistently proved when the interspace was in excess of 4 mm. Measurement of medial joint space is indicated in millimeters on each illustration. Note avulsed tip of medial malleolus attached to deltoid ligament incarcerated in joint, upper right.

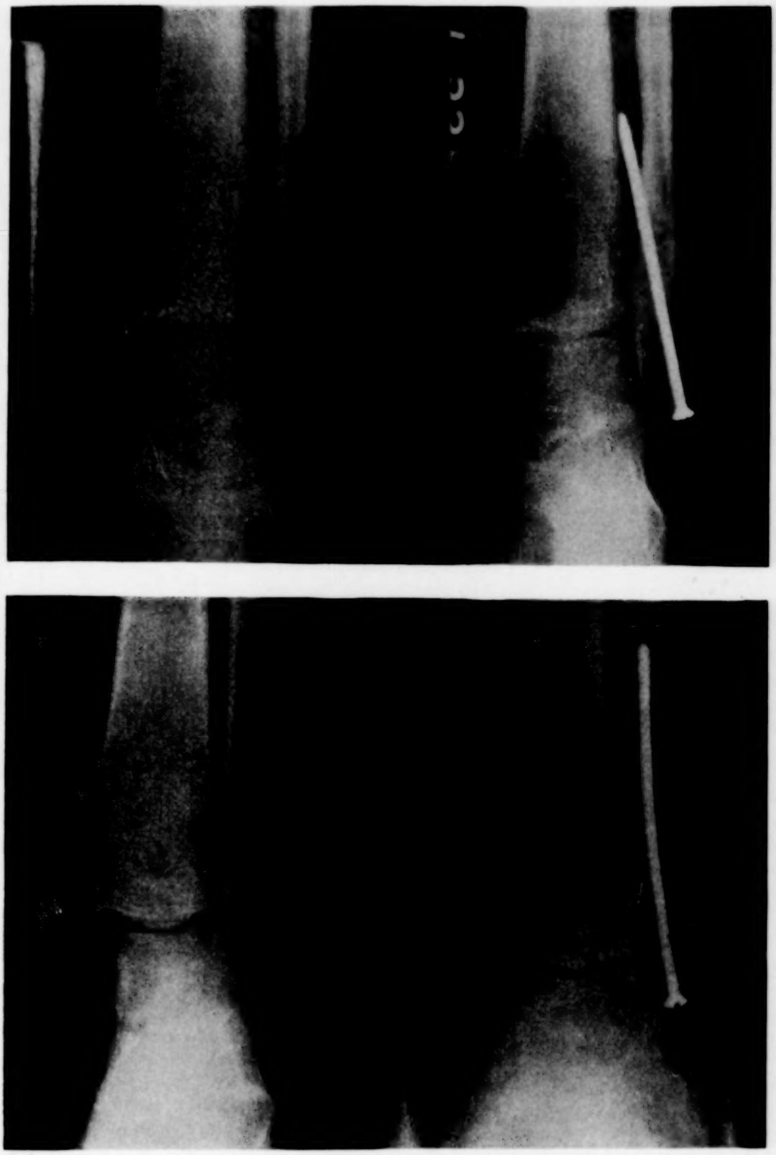

Fig. 9. *Upper:* Reconstruction of ankle five months after injury. *Lower:* Reconstruction of ankle nine months after injury.

there, in addition, a torn deltoid ligament which will need protection for eight to ten weeks? The National Ski Patrol would make a great contribution to injured skiers by promoting a transmission of early data and x-ray films from the surgeons who provide initial treatment on the ski slopes to those who must continue treatment after the injured skier returns home.

In summary, it is clear that fracture of the fibular malleolus complicated by a ruptured deltoid ligament is indeed a complex injury. It can be recognized by the surgeon who looks for it, but is frequently unrecognized or ignored with disastrous results. Successful results prerequire recognition of the presence and comprehension of the potential of the deltoid ligament rupture.

CONCLUSIONS

1. Fracture of the lateral malleolus associated with complete rupture of the deltoid ligament is a complex injury.
2. Failure to recognize its complexity has caused prolonged morbidity and threatened serious joint malfunction.
3. The findings of a ten year study of this injury are presented.
4. An increase in the medial joint space by x-ray of 4 mm. or greater is synonymous with a rupture of the deltoid ligament.
5. Late reconstruction of this injury has proved feasible.
6. A recommendation is addressed to the National Ski Patrol.

EDITORIAL*

From the surgery of trauma, modern surgery has developed a group of separate skills, interests, and techniques. Until the early 20th century all but a very small segment of the surgeon's interest and time was expended in relation to the care of the results of injury. With the development of surgery for correction of conditions other than those resulting from trauma, arose groups of surgeons whose interest and effort were directed to anatomic segments of the human body. The progress in surgery resulting from such specialization has been phenomenal. With the progress resulting from focalizing of interest has also come segmentalization of the surgical fraternity, concepts of monopoly, limitations on the breadth of training for young surgeons, and consideration of the surgical patient as a concatenation of separate, unrelated anatomic segments.

Focalization of interest is apparent in fields other than surgery, but here too the necessity of bringing all segments of related interest together is important.

The safety movement is a good example of this. For centuries, surgeons who were faced with the terrible consequences of injury were the proponents of safety. From their patients they learned the sources of injury, as well as its impact on their lives. The following, reprinted from The Lancet, 1867, indicates the forceful concern of members of the medical profession toward safety.

DANGERS OF THE STREETS. The Lancet, page 370, September 21, 1867. The authorities of Paris are said to have under consideration a project for throwing foot-bridges over the most crowded thoroughfares of that city, in consequence of the great risk attending a passage across the streams of vehicles, of which a great number are in the charge of careless or incompetent drivers. The Figaro says that every day from eight to fifteen persons are knocked down or run over by vehicles in Paris; what proportion of these are killed is not stated. In London the "dangers of the Streets" are patent to everybody, and the loss of life by accidents from vehicles amounts in a year to a very startling total. Looking through the Registrar-General's Weekly Returns, we find that since last February one hundred and eleven deaths have been registered as caused by horses or carriages in the streets, giving for the last thirty weeks an average of nearly four deaths per week. In one week ten deaths were recorded, and of these six were of persons over fifty-five years of age, and two were of children under ten years of age. The numbers receiving anything short of fatal injury are not recorded. To childhood and feeble age the passage of our over-crowded streets is full of peril, and it is not creditable to the humanity or the public spirit of the metropolitan authorities that suggestions which have often been made for erecting high foot-bridges at the most difficult crossings have not been adopted long ago. Are the Boulevards Montmartre, Capucines, and Italiens more thronged with vehicles going in all sorts of distracting directions than the Oxford-street-circus, the junction of Fleetstreet and Ludgatehill, the open space hard by the Bank and the Mansion House, the confluence of Cannon-street, King William-street, Gracechurch-street, and London-bridge, or other well-known places of excessive traffic? One of these days some peer, perhaps Sidney Smith's bishop, or other person of high

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* This editorial was prepared by Dr. Charles G. Johnston, Founding Editor, before his untimely death deprived the Journal of his leadership as editor. It thus seems particularly appropriate that his thoughts regarding this important new undertaking be recorded in this first issue of the Journal of Trauma.

> station, will get knocked down and killed by a dashing "Hansom," or one of those terrible Pickford's vans, and then possibly the authorities will be so shocked that something will be done. But a hundred or two of children and old people,—mere nobodies! It is their lot to die, and what does it matter to metropolitan or local "boards" whether they are crushed beneath the Juggernaut of the streets or not?

Despite the occasional outcry against this useless waste of "life and limb" little progress was made until special organized interest was attained in America following the establishment of the National Safety Council in 1913. Their interest has been "specialized" in the field of prevention. And in 1938 the American Association for the Surgery of Trauma was organized. Wisely the founders of this association recognized that trauma involved whole persons and was not a segmental problem; but that the skills and progress of all segments of the medical profession must be brought to focus on this important problem. The provision that membership in the association must consist not only of general surgeons, but surgeons with special anatomic interest has been an increasing source of understanding amongst surgeons and improvement in the care of the injured patient.

The Committee on Fractures of the American College began in 1921 and it later became evident that fractures were but a small part of the trauma problem. This committee, now the Committee on Trauma, is large, highly influential, and a potent force for betterment of the care of the injured, and has representatives throughout the United States.

It was only natural that these three national groups should combine their efforts against this ever increasing threat to our people. The National Safety Council, born of concern by the lay public, the American College of Surgeons and the American Association for the Surgery of Trauma dedicated to professional improvement in the care of the injured, within the past few years have coordinated their efforts in the attack on injury and death from accidents.

The medical profession can no longer assign its responsibility for accident prevention wholly to a lay organization for it is they who hold key information, available to no one else regarding the epidemiology of accidents. The National Safety Council and other lay groups interested in accident prevention can no longer be unconcerned about what happens to the victims after the accident. This is one problem and cannot be segmented strictly if we are to make progress in reducing this number one killer and crippler of our nation's most active and productive people.

The American Association for the Surgery of Trauma decided to sponsor a Journal of Trauma only after long and careful study. Papers concerned with trauma have increased in specialty journals as well as in those devoted to general surgical considerations. This is as it should be for the specialist ought have access to material concerning trauma in the field of his special interest. He cannot, however, ignore the impact of trauma on systems other than those of his special interest for they are so closely interrelated. Basic clinical and laboratory studies are often not easily available to the surgeons interested in trauma. The surgeon who cares for trauma learns of the dangers associated with new appliances early but only in isolated instances, and usually his patients must learn of such dangers from lay sources. There is need for a forum to bring such information to the medical profession as early and as completely as is possible.

The Journal of Trauma cannot hope to publish all the articles relating to trauma. Such segregation of this material would be most unfortunate for trauma touches all areas of the medical profession. However, selected articles of interest and importance to all segments of surgery must be brought together. To that end the Journal of Trauma will be edited by an editorial board consisting of recognized representatives of all branches of surgical interest. The National Safety Council has offered cooperation to provide the medical profession with information of special concern. While the purport of this Journal is to provide material on trauma of advantage to the medical profession, it is expected that safety engineers and others in the safety movement will find in it an expression of the devotion and direction of the medical profession toward those individuals for whom their efforts have proven ineffectual.

CHARLES G. JOHNSTON, M.D.

SURGEONS AND SAFETY

RALPH KUHLI, M.P.H.

National Safety Council Staff Representative to the
Policy Committee for the Joint Action Program,
American College of Surgeons,
American Association for the Surgery of Trauma,
National Safety Council

The history of the Joint Action Program starts in 1956, with a letter from the President of the American Association for the Surgery of Trauma, then Dr. Charles G. Johnston, to the National Safety Council, pointing out the necessity for those concerned with the prevention of accidents to work with those concerned with the treatment of accident victims. I replied to this letter, and the Secretary of AAST, then Dr. James K. Stack, arranged for a meeting at the Drake Hotel in Chicago in February of 1957.

The American College of Surgeons played a key role in the first developments in this program. The first formal meeting of top-level representatives of the three organizations was held during the National Safety Congress in Chicago in October of 1957. This group decided upon a Joint Action Program, formed itself into the Policy Committee and directed Dr. Paul R. Hawley, The Director of the American College of Surgeons and General G. C. Stewart, Executive Vice President of the National Safety Council, to have prepared a basic document outlining the program.

During the winter and spring of 1958, successive drafts of that document were prepared by Dr. James B. Mason, Assistant Director of the American College of Surgeons, and me. After formal clearance with all the members of the Policy Committee, this basic document was published jointly in May of 1958 as an 8½ x 11 booklet titled "Joint Action Program."

The objective of this program is a joint approach on a solid front to prevent accidents and to minimize the serious effects of trauma.

It was pointed out that the National Safety Council is concerned with the prevention of accidents, and the American Association for the Surgery of Trauma and the Committee on Trauma of the American College of Surgeons have been primarily concerned with salvage after accidents have occurred. Actually, these two aspects of the trauma problem cannot be separated; the problems of prevention and restoration are interlocking. Together, the National Safety Council and the surgical organizations principally concerned with trauma can do much to minimize accidents and the serious effects of accidents.

This basic policy document, Planning Memorandum No. 1, and state lists of surgeons and Safety Council managers were mailed on the same day to state and local Trauma Committees and to state and local Safety Councils. In each state, a representative of the American College of Surgeons and a representative of the safety councils there were asked to serve as coordinators and to promote this program jointly in the state. In communities fortunate enough to have both a Committee on Trauma and a Safety Council, the two groups were urged to work together on the development of a local Joint Action Program.

The projects suggested for joint action were (and still are) concerned with adequate training in handling of the accidentally injured by ambulance attendants and others; community-wide promotion of attendance at courses of instruction in accident prevention and first aid; and effective, vigorous support at the State and local levels of the objectives of the President's Committee for Traffic Safety. In July of 1959, Planning Memorandum No. 2 added new projects for the promotion of seat belts and for safety in sports.

A special section on Transportation of the Injured was included in the National Safety Council's 1958 Inventory of Traffic Safety Activities, and from the 865 cities which returned completed questionnaires, Dr. Oscar P. Hampton wrote a report which was printed in the January-February 1960 *Bulletin* of the American College of Surgeons and reported in the January 1960 issue of *Traffic Safety* Magazine.

Meanwhile, Dr. George J. Curry, presented a paper on "The Immediate Care and Transportation of the Injured" as the 26th Oration on Trauma at the American College of Surgeons' Clinical Congress in 1958, and co-authored articles on the speeding ambulance. For Dr. Curry's outstanding leadership in national and local programs for the transportation of the injured, he was presented with the National Safety Council's first Surgeons' Award for Distinguished Service. President Howard Pyle presented the award October 17, 1960, at the National Safety Congress in Chicago.

An example of a Local Joint Action Program may be seen in Phoenix, Arizona. The President of the Arizona Chapter of ACS, Dr. MacDonald Wood, is Chairman and the Managing Director of the Maricopa Safety Council, Mr. J. Scotty Wallace, is Advisor, of a City-County Citizens Committee appointed by the Maricopa County Board of Supervisors and the Phoenix City Council for a study of emergency ambulance service. An exhaustive study has been made and a preliminary report was drafted in October 1960.

The Policy Committee for the Joint Action Program plans and allocates projects and programs. The Chairman is Dr. George M. Wheatley, a member of the Executive Committee of the Board of Directors, National Safety Council. Vice Chairman is Dr. Preston A. Wade, and the other members are the top representatives of the three sponsoring organizations. Dr. James B. Mason and I serve as staff representatives, and it is my privilege to work very closely with him. Dr. Wheatley plans to call the next meeting of the Policy Committee early in 1961.

Dr. Hawley and General Stewart agreed on the opportunities offered by this Joint Action Program when in May of 1958 they signed their names to this statement:

> "Here is provided an organizational pattern which, fully exploited, will bring great benefits to individuals and to the public."

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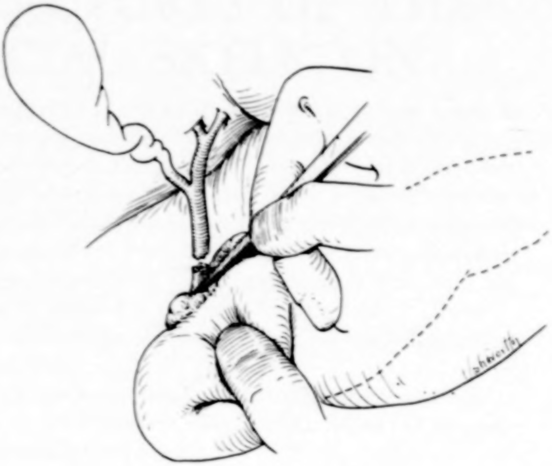


FIG. 1

Diagrammatic sketch showing site of complete rupture of the common duct. The distal segment has been dissected from the pancreas.

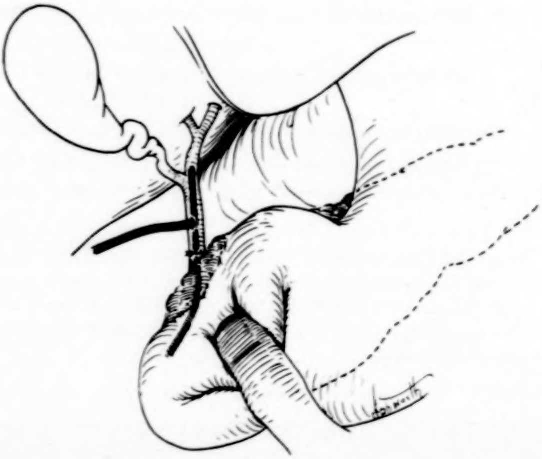


FIG. 2

Diagrammatic sketch showing method of reconstruction of the biliary tract by end-to-end anastomosis of the divided duct.

COMPLETE DIVISION OF THE COMMON BILE DUCT DUE TO BLUNT TRAUMA

Report of a Case and Review of the Literature

WILLIAM S. FLETCHER, M.D., DONALD E. MAHNKE, M.D. AND
J. ENGLEBERT DUNPHY, M.D.

From the Department of Surgery, University of Oregon Medical School

Rupture of the extrahepatic biliary system from blunt trauma to the abdomen is an unusual occurrence. Mason, (10) in an excellent review of the subject in 1954 stated, "The exact number of reported cases is difficult to determine because of the many cross references and duplications in published reviews. There are probably less than 100 cases recorded in the last century."

Complete division of the common bile duct from blunt trauma to the abdomen as a solitary lesion is an exceedingly rare disease. We have recently encountered a case and have found five in the literature. Two additional instances have been found in which there were other major intra-abdominal injuries. Because this injury presents an insidious but definite clinical picture, and is uniformly fatal without surgical intervention, the authors present this case with a review of literature in an attempt to elucidate the mechanism of the injury.

CASE REPORT

K. P., a 54-year old, white, male, itinerant laborer, entered the Multnomah County Hospital on February 10, 1960, complaining of abdominal pain and vomiting. Approximately 36 hours prior to admission, he had been attacked and robbed after an evening of drinking. His assailant had knocked him down and kicked or jumped on his upper abdomen. Following the attack, the patient felt well enough to drive a truck to a town 100 miles distant and return. On the morning of admission, he noted crampy abdominal pain with radiation to the right shoulder and vomited "coffee-ground material." He had not had a bowel movement for three days, despite cathartics.

Physical examination revealed a well-developed, well-nourished, middle aged white male appearing in moderately acute distress from abdominal pain. Pulse 120 per minute; B.P. Systolic 120—Diastolic 90; Resp. 28 per minute and temperature 101.4° Fahrenheit. Positive findings were as follows: The respirations were short and shallow. There was an old, left transverse subcostal scar, bowel sounds were absent; tenderness, rebound tenderness and spasm were present throughout the abdomen, most marked in the right epigastrium; there were no

Discussion of this paper is included with that of the following paper by Dr. Burrus and associates.

Read before the Twentieth Annual Session of The American Association for the Surgery of Trauma, Coronado, California, October 5-7, 1960.

signs of trauma to the abdominal wall and no marks on the skin. No masses could be felt in the abdomen. The rectal examination was negative.

Laboratory studies were as follows: Hematocrit 52; White Blood Count 14,480 with 81 per cent segmented neutrophiles. A non-catheterized urine specimen contained a trace of protein and occasional pus cells. The gastric aspirate was "coffee-ground" in color and strongly positive for occult blood by the orthotoluidine test. X-rays of the chest showed old left rib fractures and films of the abdomen revealed moderate amounts of gas in the bowel, largely in the colon. There was no free air under the diaphragm.

Following a three-hour period of preparation with parenteral fluids and nasogastric suction, exploratory laparotomy was performed under general endotracheal anesthesia with a preoperative diagnosis of ruptured viscus. The peritoneum contained approximately 500 cc. of bile; there was edema and bile staining over the hepatoduodenal ligament, the first and second portions of the duodenum, the hepatic flexure of the colon and the right gutter, lateral to the colon. There was a small hematoma on the left side of the inferior leaf of the mesocolon. Exploration was otherwise unremarkable except for the gall bladder which was large, thin-walled and edematous. The cystic duct was large. Pressure on the gallbladder caused dark green bile to flow from a pin-point hole in the peritoneum over the common bile duct at a point just above the first portion of the duodenum. The hepatic flexure of the colon was reflected inferiorly and the duodenum medially. This exposure revealed complete avulsion of the common bile duct at its junction with the pancreas (Fig. 1).

Bile could easily be expressed from the proximal end of the common duct with slight pressure on the gall bladder. The duct was about 7 mm. in diameter, thin walled and moderately edematous. The distal end of the duct was seen entering the pancreas as in Figure 1. The proximal portion of the duct was mobilized for approximately three cm. and an end-to-end repair performed over a short, number 12 French T Tube placed in the duct above the injury so as to pass through the point of avulsion, but not through the sphincter (Fig. 2). The abdomen was closed with drainage. Postoperatively, the patient's course was uneventful. The drain was removed on the 14th postoperative day. T-Tube cholangiograms on the 15th and 22nd postoperative day showed good filling of the distal common duct and biliary radicals. On the 27th postoperative day, pressures of the biliary system were taken, using a strain gauge. The resting biliary secretory pressure was 12.8 mm. of mercury, the mean sphincteric release pressure was 24.8 mm. of mercury and the mean pancreatic secretory pressure was 36 mm. of mercury as determined by reflux of contrast agent into the pancreatic duct from the common bile duct. On the 31st hospital day, the T-Tube was removed after being clamped for 48 hours without ill effect. Three days later, the patient was discharged.

REVIEW OF REPORTED CASES FROM THE LITERATURE

Complete severance of the common bile duct as a result of blunt trauma to the abdomen is so rare that no author has more than one case to report. We have, therefore, summarized in Table 1 the features of this case and seven collected from literature. Several points are of interest. Only five cases were reported from 1893 to 1958, but three have been reported in the last two years. The age of the patients varied from four to 54 years with a mean of 25 years. All of the patients were relatively young, and sustained crushing blows across the upper abdomen.

The time interval between injury and operation has been amazingly long. Only the two patients, (Cases Four and Five) with associated injuries were operated upon within 24 hours. Five did not come to operation until one and one-half to twenty days following injury. It is not stated what the interval was in Case Three, but the repair was described as being "extremely difficult" due to trauma, hemorrhage, edema and disruption of the gastrohepatic ligament (8) which suggests that operation was not early. Two of the eight patients had no associated injury, three received minor injuries and only two had associated major intra-abdominal injuries.

TABLE 1

Common Bile Duct Severance by Blunt Trauma

Summary of Reported Cases

Case	Author Year	Age	Injury	Delay before operation	Associated injury	Site of rupture	Type repair	Result
1.	Battle 1893	6	Run over by hansom cab	7 days	None	Junction with pancreas	Drainage	Died 8th day
2.	Spencer 1898	5	Run over by hansom cab	13 days	Separation Rt. 9th costochondral junction	Junction with pancreas	Drainage	Died 33rd day
3.	Ladd & Gross 1941	4	Crushed by auto bumper against wall	Not stated	None	Below cystic duct	1° repair, 2° cholecystoduodenostomy	2° stricture of varices 8 years later
4.	Just 1926	18	Run over by oxcart	Within 24 hours	Tear, sup. mes. artery. Ruptured liver, pancreas, and spleen	Junction with pancreas	1° repair over catheter	Died of postop hemorrhage
5.	Lysaght 1939	32	Thrown against steel girder	Within 24 hours	Ruptured duodenum	Junction with pancreas	Cholecystogastrostomy & ligation of prox. CBD.	Well 2 mo. later
6.	Donald & Donald 1958	43	Struck across upper abdomen by steel bar	7 days	Fx. ribs 7-9. Bruise on back	Junction with pancreas	1° repair over T tube & cholecystectomy	Well 2 yrs postop.
7.	Tolins 1959	36	"Steering wheel injury"	20 days	Renal contusion	Junction with pancreas	1° repair over T tube	Well 6 mo. postop.
8.	Fletcher, Mahnke & Dunphy 1960	54	Kicked in upper abdomen	36 hours	None	Junction with pancreas	1° repair over T tube	Well 10 weeks postop.

The site of complete rupture of the common duct is remarkably similar in all of the cases. It is known to be at the junction of the common duct with the pancreas, as shown in Figure 2 in all but Case Three in which the site was distal to the cystic duct because a subsequent cholecystoduodenostomy was performed.

Treatment has varied. In Cases One and Two, the abdomen was only drained, and the diagnosis was not established until autopsy. In Case Five, the distal common duct could not be found so that cholecysto-gastrostomy and ligation of the proximal remnant of the common duct was done. Five patients underwent primary anastomosis of the common bile duct. One of these died in the immediate postoperative period of bleeding from associated injuries. In Case Three subsequent cholecysto-duodenostomy for secondary stricture was necessary. Death occurred eight years later from recurrent cholangitis and cirrhosis with bleeding esophageal varices (3). Three patients in which primary repair and one in which cholecysto-gastrostomy were performed have remained well for follow-up periods varying from 10 weeks to two years.

CLINICAL MANIFESTATIONS

Two fairly clear cut clinical syndromes occur in rupture of the extrahepatic biliary system due to non-penetrating trauma. If there is an associated rupture of a hollow viscus the classical signs of an acute abdomen will be found. This is not common, only two of the reported cases fit this pattern. In such cases the injury to the common duct can easily be missed as Lysaght has emphasized (9). The exact nature of the injury may not be immediately obvious and, in the presence of other obvious injuries, could easily be overlooked. When doubt as to the status of the duct exists, the duodenum must be reflected medially and the common bile duct examined. This is particularly true when there is bile staining of the peritoneum in that area.

Rupture of the common duct as the only intra-abdominal lesion produces an insidious syndrome first recognized by Fizeau and well described by Battle in 1893 (1). Contrary to popular belief, normal bile in the free peritoneal cavity does not always cause the signs and symptoms of an acute abdomen (4, 7). This accounts for the paucity of findings in rupture of the extra-hepatic biliary system when it occurs as an isolated injury. Without awareness of this fact it may be difficult, if not impossible, to make the diagnosis early.

TABLE 2

Rupture of Common Bile Duct by Blunt Trauma Signs and Symptoms

Fever	7	Constipation	4
Nausea, vomiting	6	Distention	4
Tenderness	6	Transient "shock"	3
Mild to moderately severe pain	5	Dullness to percussion	3
Jaundice	4	Acholic stools	3
Spasm	4	Bile in urine	2

G.I. Bleeding was noted in authors' case and should be an important sign. It was not mentioned in reported cases.

The signs and symptoms have been tabulated in order of frequency of appearance in Table 2. Although not all the case reports include all this information, the relative frequency of the reported signs and symptoms gives some indication of the nature of the findings in the average case. Of particular note is the fact that only the two patients with an associated perforated viscus complained of severe abdominal pain. Five of the eight patients were described as having only mild to moderate pain and none of the patients had markedly elevated temperatures. In two instances, the temperature was below normal at the time of admission. In four of the cases in which operation was delayed beyond four days jaundice developed, and in three instances there were acholic stools. Four patients were noted to have constipation and distention while in three there was shifting dullness to percussion over the abdomen suggesting the presence of fluid. Two patients had bile in the urine. None of the patients had evidence of trauma to the skin of the abdomen.

None of the eight patients suffered damage to the portal vein or hepatic artery, and in only two cases was there damage to the liver or duodenum. Just how the duct can be torn in two without injury to the portal vein, duodenum, pancreas or hepatic artery is hard to explain. A shearing force should injure adjacent structures so the possibility of a "blow-out" of the duct from increased intraluminal pressure must be considered. An attempt has been made to determine the nature of the injury experimentally.

EXPERIMENTAL OBSERVATIONS

To determine whether rupture of the common bile duct might occur from a sudden increase in the intraluminal pressure, an attempt was made to rupture the biliary tree in the experimental animal.

Methods: Goats were chosen because the pancreatic duct enters the common bile duct proximal to the ampulla of Vater, as shown in Figure 3 and permits easy isolation of the biliary from the pancreatic system. Figure 4 is a diagram of the apparatus used to distend the biliary system. This consisted of a cylinder of oxygen or carbon dioxide connected by a short tube to a reservoir of colored saline. A long tube from below the saline level in the reservoir was connected by a thick-walled rubber tube to a number 18 metal cannula. The animals were anesthetized with intravenous sodium pentobarbital and the abdomen opened through a right subcostal incision. The duodenum was opened and the cannula passed through the ampulla into the lower common bile duct where it was tied securely in place by a circumferential ligature about the duct. Thirteen experiments were made on a total of five animals. Following rupture of the pancreas or gallbladder, the respective ducts were clamped and further trials continued. Initial attempts to distend the duct by injection with a syringe and three-way stop-cock resulted in the appearance of fat necrosis on the surface of the pancreas after approximately 500 cc. of saline and 5 minutes elapsed time. There was no evidence of rupture of the bile ducts. The apparatus, as shown in Figure 4, was then connected to the cannula.

Results: The results are shown in Table 3. Oxygen at a pressure of 2200 lbs. per sq. in. was applied to the system. This resulted in rupture of the common bile duct at the site of the ligature on three occasions and rupture of the intrahepatic portion of the gallbladder on one occasion. This was thought possibly to be an artifact from trauma to the duct by the ligature about the cannula. As it was difficult to devise a system which would not break down under the pressure from the oxygen cylinder, carbon dioxide was substituted for oxygen.

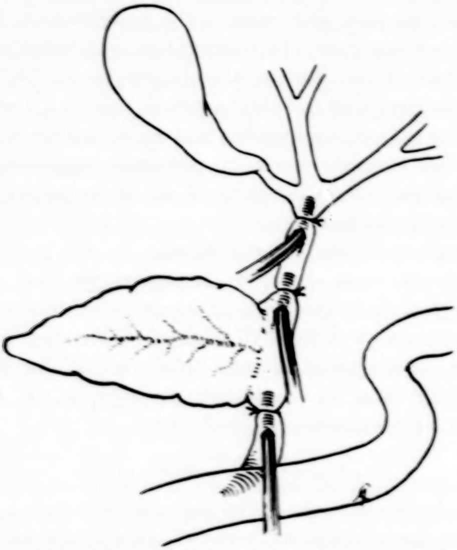
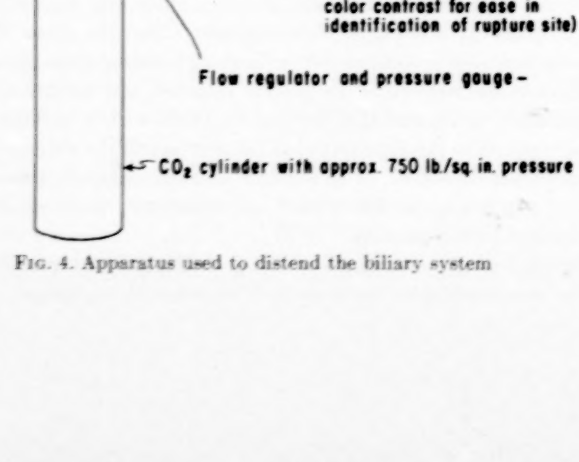


FIG. 3. Diagrammatic drawing of the biliary tract of the goat. The sites of cannulation of the biliary tract are depicted.



Rubber tubing - all connections tied securely
To goat gall bladder
Taped bottle with water and ink solution (ink to provide color contrast for ease in identification of rupture site)
Flow regulator and pressure gauge -
CO₂ cylinder with approx. 750 lb./sq. in. pressure

FIG. 4. Apparatus used to distend the biliary system

TABLE 3

Results of Experimental Work

Effect of Sudden Distention of Common Bile Duct of Goats

Group	Location	Pressure (lbs. per sq. in.)	Results
Group A			
Exp. 1	Below pancreas	Low	Rupture of pancreas
Exp. 2	Below pancreas	2200	Rupture at ligature
Group B			
Exp. 1	Below pancreas	2200	Rupture of pancreas and C.D. at ligature
Exp. 2	Above pancreas	2200	Rupture at ligature
Exp. 3	Above pancreas	2200	Rupture of gallbladder
Group C			
Exp. 1	Below pancreas	600	Rupture of pancreas and gallbladder
Exp. 2	Below gallbladder, above pancreas	750	No rupture, C.D. rigid but intact
Group D			
Exp. 1	Below pancreas	600	Rupture of pancreas
Exp. 2	Above pancreas	750	No rupture of G.B. or C.D.
Exp. 3	Above pancreas	750	No rupture of G.B. or C.D.
Group E			
Exp. 1	Below pancreas	600	Rupture of pancreas
Exp. 2	Above pancreas	750	No rupture of C.D. or G.B.
Exp. 3	Above pancreas	750	No rupture of C.D. or G.B.

A system of gauges was arranged to allow the sudden application of pressures up to 750 lbs. sq. in. With this apparatus, eight trials were made on three animals. At pressures varying from 100 lbs. sq. in. to 600 lbs. sq. in., the pancreas became edematous, showed evidence of fat necrosis and leakage of the perfusing fluid. After clamping of the pancreatic duct, pressures of 600 lbs. sq. in. were again applied with rupture of the fundus of the gallbladder on one occasion. Thereafter, pressures of 750 lbs. sq. in. were applied a total of seven times in three animals without rupture of the gallbladder or common bile duct. Despite the fact that the heavy rubber tubing used in the system became distended to five times the usual size of the tubing there was no dilatation of the common duct.

DISCUSSION

In all the reported cases, the common bile duct was completely divided at or near its junction with the pancreas without evidence of major trauma to other structures in the porta hepatis. If the injury is produced by crushing of the duct against the spine or traction on the duct, it seems inconceivable that there is no damage to the thin-walled portal vein. Since in the case presented, the cystic duct was short and wide, which allowed for rapid emptying of the gallbladder, the authors have postulated that this might be a "blowout" type of injury resulting from a sudden increase in the intraductal pressure. The fact that the duct always seemed to rupture at the superior border of the pancreas might be explained by the relative support of the head of the pancreas about the duct at this level, even though the circular sphincter of the duct does not start until the duct enters the wall of the duodenum (5).

The authors do not feel that these experiments are conclusive proof of the mechanism of injury. However, it seems most unlikely that blunt trauma to the abdomen would create pressures greater than 750 lbs. sq. in. in the common bile duct. Therefore, some combination of factors must be at play to explain the injury. The necessity for several factors may explain the rareness of the injury. In our experiments, a sudden increase in intraluminal pressure distended the common bile duct and rendered it rigid. A shearing force applied at this time would conceivably divide the rigidly distended duct while sparing the more pliable adjacent structures. The tear occurs at the entrance to the pancreas just as small bowel injuries occur at points of fixation. Thus, one can postulate that three factors are required for complete division of the common bile duct from blunt trauma to the abdomen: 1. A short wide cystic duct so as to allow rapid emptying of the gallbladder. 2. A force applied adjacent to the gallbladder to empty it rapidly. 3. A simultaneous shearing force to the common duct. Any of the injuries in the reported cases could have provided the latter two of these conditions. The type of cystic duct was not described in the reported cases but was of the short wide type in our case, thus fitting the hypothesis.

TREATMENT

Successful treatment of complete division of the common bile duct depends on restoration of bile flow into the gastro-intestinal tract. Although simple drainage of the abdomen has been successful in some cases of partial rupture of the bile ducts (4, 10), it has been uniformly fatal in cases of total ruptures (1, 11). Direct repair of the severed duct over a splinting catheter or T-Tube appears to be the treatment of choice (2, 3, 6, 8, 10, 12) despite Walker's statement that he has "Found no record in which direct repair of a torn duct has been successfully accomplished without subsequent stricture." Of the five cases in this series so treated, one died in the immediate postoperative period and one required subsequent cholecystoduodenostomy for secondary stricture at the anastomotic site. Three patients with primary repair of the duct have done well for follow up periods varying from ten weeks to two years at the time of reporting.

SUMMARY

A case of complete severance of the common bile duct as a result of blunt trauma to the abdomen is presented and seven cases from the literature are reviewed. Experimental attempts to rupture the common bile duct resulted in rupture of the pancreas at low pressures, rupture of the gallbladder at high pressure on two occasions and no rupture of the common bile duct with pressures up to 750 lbs. sq. in. The following conclusions are drawn:

Complete severance of the common bile duct as a result of blunt trauma to the abdomen is a rare injury produced by a crushing blow across the upper abdomen and lower chest, delivered while the back is supported. The common duct ruptures at the superior border of the pancreas without injury to the portal vein or hepatic artery. A mechanism for this rare lesion is postulated on the basis of the clinical and experimental data.

Successful treatment depends upon restoration of the flow of bile into the gastrointestinal tract.

BIBLIOGRAPHY

1. Battle, W. H.: Traumatic rupture of the common bile-duct. Tr. Clin. Soc. Lond., **27:** 144–148, 1893.
2. Donald, J. W. and Donald, J. G.: Complete severance of the common bile duct due to non-penetrating trauma, Ann. Surg., **148:** 855–858, 1958.
3. Gross, R. E.: The Surgery of Infancy and Childhood, W. B. Saunders Company, Philadelphia and London, 1953.
4. Hicken, N. F. and Stevenson, V. L.: Traumatic rupture of the choledochus, associated with acute hemorrhagic pancreatitis and a bile peritonitis, Ann. Surg. **128:** 1178–1183, 1948.
5. Hollingshead, W. H.: The lower part of the common bile duct: A review, Surg. Clin. N. America, p. 939–952, Aug. 1957.
6. Just, E.: Subcutaneous total rupture of choledochus, Arch. f. klin. Chir., **140:** 518–527, 1926.
7. Ladd, W. E.: Toxicity of bile with the report of an unusual case, Boston M. & S.J., **168:** 166, 1931.
8. Ladd, W. E. and Gross, R. E.: Abdominal Surgery of Infancy and Childhood, W. B. Saunders Company, Philadelphia and London, 1941.
9. Lysaght, A. C.: Case of traumatic severance of common bile-duct, Brit. J. Surg., **26:** 646–648, 1939.
10. Mason, L. B., Sidbury, J. B., and Guiang, S., Rupture of extrahepatic bile ducts from nonpenetrating trauma, Ann. Surg., **140:** 234–241, 1954.
11. Spencer, W.: A case of rupture of the common bile duct, Lancet, **1:** 100–101, 1898.
12. Tolins, S. H.: Complete severance of the common bile duct due to blunt trauma: A case report, Ann. Surg. **149:** 61–64, 1959.
13. Walker, J. H. M.: Traumatic rupture of bile-ducts, Lancet, **2:** 969–971, 1953.

TRAUMATIC DUODENAL INJURIES: AN ANALYSIS OF 86 CASES

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The mortality rate following duodenal injury has remained consistently high during the past century. Early in the nineteenth century it approached 100 per cent and in the early twentieth century, Miller (7), evaluating 45 reported cases of retroperitoneal rupture of the duodenum treated surgically, reported a mortality rate of 89 per cent. There was no significant change in World War I (6), but during World War II there was some decrease in mortality, Cave (3) reporting 118 patients treated with a mortality rate of 57 per cent.

A review of the recent literature published from civilian institutions indicates that this lesion is rarely encountered, for most articles included less than 5 patients treated (4, 5, 8, 10). The current report consists of a review of 86 patients treated surgically during the period 1940 to 1960. Fifty of these have been the subject of a previous joint publication from the departments of surgery of Baylor University College of Medicine and Emory University School of Medicine (12). The remaining 36 patients were treated during the past 4½ years at the Jefferson Davis and Veterans Administration Hospitals, Houston, Texas.

CLINICAL MATERIAL

Duodenal injuries were encountered in patients ranging from 5 years to 58 years of age, 50 per cent occurring in the age group between 20 and 40 years. The majority of the patients were male. Seventy-seven wounds were penetrating in type, including 15 stab wounds, 56 bullet wounds, and 6 shotgun wounds. Of the 9 patients sustaining blunt trauma, 5 were injured in automobile accidents, one was injured from a fall and 3 received blows during fights.

Perforation of the duodenum occurred in all of the patients with penetrating injury and in 8 of the 9 patients having blunt trauma. In 76 patients (88 per cent) there were simple lacerations or perforations while in 10 patients (12 per cent) more extensive injuries occurred. In 2 with gunshot wounds the duodenum sustained severe trauma with multiple perforations. In 4 patients there was more than 50 per cent transection and in 3 patients the duodenum was completely severed, once in the third portion, once in the fourth portion, and once in the pyloric junction. A tenth patient was stamped repeatedly in the stomach during a fight. Being acutely intoxicated he delayed seeking medical aid for 12 hours when he presented with findings suggesting an acute intra-abdominal process. At operation it was found that the head of the pancreas

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had been avulsed from the second portion of the duodenum with extensive contusion and inflammation of the duodenum and the periduodenal area, but with no significant ischemia. This wound is classed as severe trauma, although it was the only injury in which actual perforation did not exist. Blunt trauma was associated with severe injury in a high percentage of patients—67 per cent. In only 4 (5.2 per cent) patients with penetrating wounds was the trauma to the duodenum extensive.

The perforations occurred into the free peritoneal cavity in 93 per cent and into the retroperitoneal region in 7 per cent. The second portion of the duodenum, which is the longest, was injured most frequently, in 43 per cent of patients. More than one portion sustained injury in 10 instances (Table I). There were injuries of associated organs in 81 patients, the duodenum being the only organ injured in but 5. The organ most frequently injured was the liver (Table II).

TABLE I

Portion of Duodenum Injured*	Penetrating	Blunt	Total
First Portion	12	1	13
Second Portion	31	3	34
Third Portion	11	2	13
Fourth Portion	12	2	14
Combined	9	1	10
Total	75	9	84

* Two cases did not record portion injured.

TABLE II

Associated Organ Injury

Associated Injury	Number of Patients	Per Cent
Liver	32	37
Small Bowel	30	35
Stomach	24	28
Transverse Colon	24	28
Pancreas	23	27
Right Kidney	21	24
Vena Cava	11	13
Ureter	9	10
Gall Bladder	8	9
Common Bile Duct	4	5
Aorta	4	5
Superior Mesenteric Artery	3	3
Superior Mesenteric Vein	2	2
Mesentery of Colon or Small Bowel	2	2
Renal Vein	2	2
Inferior Mesenteric Artery	1	1
Inferior Mesenteric Vein	1	1
Miscellaneous	19	22

There were 24 associated injuries of major vessels. Of particular importance were the associated injuries of the pancreas, which significantly complicated the postoperative course in a number of patients.

CLINICAL FEATURES

All patients exhibited findings suggesting intra-abdominal injury at the time of admission. In the patients having penetrating wounds the penetration of the abdominal wall was considered adequate indication for operation. Abdominal exploration was warranted in the patients having blunt injuries on the basis of clinical findings. In no patient was a specific diagnosis of duodenal injury made, for special diagnostic procedures such as examination of the gastrointestinal tract with radio-opaque material were thought to be contraindicated in acutely ill patients. Many of the patients were in a severe state of shock due to blood loss resulting from major vessel injury and operation was performed as soon as possible after admission. In those patients whose condition was not too critical, intravenous pyelography was performed prior to operation to investigate the possibility of associated renal or ureteral injury.

TREATMENT

The initial treatment of the patient was dependent upon his clinical state on admission. As has already been mentioned, the associated injuries frequently were more significant than the duodenal injury in producing hemorrhage and shock. Thus, resuscitative measures were undertaken in the emergency room and the patient was taken to the operating room as soon as possible. At the time of operation the duodenum was specifically examined. Hemorrhage, bile staining, edema and crepitation in the periduodenal area were considered suggestive evidence of duodenal injury. In one instance there was fat necrosis.

During exploration of the duodenum the first and second portions were mobilized by incising the lateral peritoneal attachments to inspect the retroperitoneal portion of the duodenum as well as the ureter, kidney, renal vessels and vena cava. The third and fourth portions were mobilized as indicated for adequate examination. The duodenal injury was diagnosed at the time of exploration in all but two patients. One patient, previously reported, had an injury to the fourth portion of the duodenum which was overlooked because the ligament of Treitz was not divided (12). Diagnosis was made when duodenal contents drained from the wound on the second postoperative day and the lesion was repaired in a second procedure. In the second patient the diagnosis was made at necropsy. One patient died during operation before treatment of the duodenal wound was undertaken.

The simple lacerations and perforations were debrided and closed in layers in either a transverse or longitudinal direction, depending upon the nature of the wound. No specific attempt was made to close wounds transversely if longitudinal closure did not compromise the lumen. In more extensive wounds an anastomosis was necessary. Thus, the treatment consisted of duodenorrhaphy in 78 patients, duodenoduodenostomy in 2, duodenojejunostomy in 2, gastroduodenostomy in 1 and the patient having contusion only was treated simply with drainage. Gastrojejunostomy was performed as an additional procedure in 8 patients in whom closure of the duodenal wound appeared to compromise the lumen to such an extent that obstruction was feared and in whom there was some concern regarding possible failure of primary healing of the duodenal wound because the closure of the perforation was in a contused area. Drainage of the region of the duodenal repair was performed in most instances.

MORTALITY

Twenty-three per cent of these patients died during operation or in the postoperative period. The mortality following penetrating wounds and blunt trauma was essentially the same. When one considers the method of wounding, however, there was a significant difference in the mortality rate of knife wounds as compared to bullet and shotgun wounds for there were no deaths in the former group while in the patients with shotgun wounds the mortality was 83 per cent (Table III). As has been true in other studies of intra-abdominal injuries there was a correlation between the number of injuries to other organs or vessels and the mortality rate. Of particular importance were injuries to major vessels, there being a 50 per cent mortality rate in patients sustaining wounds to the aorta and a 36 per cent mortality rate in patients sustaining wounds to the vena cava. In fact, the most common cause of death was hemorrhage and shock and the second most common cause of death was post-traumatic renal insufficiency (Table IV). In some of the latter patients the renal insufficiency was undoubtedly the result of prolonged periods of shock or transfusion reactions, so that hemor-

TABLE III

Mortality Related to Mode of Injury

Type of Injury	Number of Patients		Mortality			
			Number		Per Cent	
Penetrating	77		18		23	
Knife		15		0		0
Bullet		56		13		23
Shotgun		6		5		83
Blunt Trauma	9		2		22	
Total	86		20		23	

TABLE IV

Cause of Death

Hemorrhage and Shock	8
Post traumatic Renal Insufficiency	4
Intra-abdominal Infection	4
Duodenal Fistula	1
Massive Chest Injury	1
Stress Ulcer with Subsequent Uremia	1
Cause not adequately explained	1

rhage and shock was the leading cause of death by a large margin. Intra-abdominal infection was also a frequent cause of death for 5 per cent of all patients died of this complication; and infection was the cause of death in 20 per cent of the 20 patients who died. It was gratifying, however, in comparing the two periods, to find that all of the deaths from intra-abdominal infection occurred in the earlier period of the study and that in the last 4½ years there have been no deaths attributed to infection. Direct complications of the duodenal injury were not a common cause of fatality, only one death being attributed to duodenal fistula.

COMPLICATIONS

Abscess: Intra-abdominal abscess was the most frequent complication encountered in this study, being present in 14 per cent of all patients (Table V). The most common site of abscess was the subphrenic space but abscesses were encountered throughout the abdomen, in the cul de sac of Douglas, in the right and left gutters and in the region of areas of trauma. Treatment was by drainage and, in recent years, antibiotics.

Pancreatic Complications: It is of interest that in this group of patients injuries to an adjacent organ accounted for a greater number of complications than did the injury to the organ under study. As previously mentioned, the incidence of associated pancreatic injury was extremely high, such wounds being present in almost 27 per cent of patients. A complication developed in 10 per cent of patients (40 per cent of patients with pancreatic wounds). The pancreatic complications added significantly to the morbidity in some patients but in no instance were these complications a cause of mortality.

Duodenal Complications: There were 6 complications directly related to the management of the duodenal wound. All of the 4 fistulas occurred following gunshot wounds which were treated by duodenorrhaphy. Gastrojejunostomy had been performed in one instance. Although the presence of the gastrojejunostomy did not protect the patient from fistula formation, it did aid in the management of the problem. The patient was placed on the left side. Duodenal

TABLE V

Intra-abdominal Complications

Abscess	12	
Subphrenic		5
Others		7
Pancreatic	9	
Fistula		6
Pseudocyst		3
Duodenal	6	
Fistula		4
Obstruction		2
Intestinal Obstruction	6	
Ureteral Fistula	2	
Fecal Fistula	1	

drainage was collected by sump suction for refeeding, and it was possible to maintain fluid and electrolyte balance by oral ingestion of an adequate diet. Three of the 4 duodenal fistulas closed within 2 months. The fourth patient died. In this patient the duodenal injury had been overlooked at the initial operation and became apparent following drainage of the duodenal contents from the wound. Duodenorrhaphy was performed at a second procedure but the fistula recurred and in spite of supportive therapy the patient died on the twenty-fourth postoperative day as a result of nutritional, fluid, and electrolyte problems. It is possible that this death would have been prevented had the duodenal wound been properly treated at the time of the first operation.

Duodenal obstruction developed in 2 patients. In each instance this was treated by gastrojejunostomy without further difficulty.

Miscellaneous: Intestinal obstruction, ureteral fistula and fecal fistula were the other intra-abdominal complications of significance, though in no instance were these complications associated with mortality.

DISCUSSION

The duodenum is a fixed structure lying deep within the abdomen where it is protected on all sides from external injury by the surrounding soft tissues and abdominal musculature. The rigid vertebral column may, under certain circumstances, however, act as a buttress against which the duodenum can be crushed. The pyloric sphincter and the acute angulation at the jejunal junction may produce a closed, fluid-containing viscus subject to blow-out on compression.

Penetrating wounds of the abdomen should lead to a diagnosis of acute intra-abdominal injury in most instances; however, retroperitoneal rupture of the duodenum by blunt trauma may constitute a serious challenge in diagnosis for the classical signs of intra-abdominal injury may be delayed and in rare instances the duodenum will be injured under circumstances which would suggest minimal external trauma. However, proper clinical evaluation of the patient should lead to a diagnosis of intra-abdominal injury. It is not necessary to demonstrate the presence of duodenal injury specifically before operation. The utilization of barium by mouth for this purpose is not only unnecessary but may actually be harmful. When celiotomy is performed, thorough exploration of the duodenal region is mandatory, mobilizing the structure sufficiently to examine it completely.

These data demonstrate that when diagnosed promptly duodenal wounds can be treated properly in most instances, without the development of serious complications. Thus, fistula formation developed in only 4 per cent of patients in which the duodenal injury was recognized at the time of the first operation. Nevertheless, adequate drainage should be instituted routinely, for if fistulas which develop are drained to the exterior without contamination of the free-peritoneal cavity, the management will be less complicated. In the current series the response of these fistulas to treatment was extremely gratifying in that 3 of the 4 patients survived and the fistulas closed spontaneously. These were all lateral fistulas rather than end fistulas and the mortality rate for treatment of this type of fistula is commonly reported to be 40 per cent or higher (2). No surgical therapy was necessary in the management of either of these fistulas; however, performance of a gastrojejunostomy to bypass the area of leakage may be of benefit in some instances. Albright and Leonard (1) have summarized the treatment of duodenal fistula as: "1) prevention of tissue digestion by pancreatic enzymes 2) maintenance of fluid, electrolyte and nutritional balance and 3) ultimate closure of the fistula and restoration of the intestinal tract." We prefer the use of the sump drain as a primary method of maintaining good skin hygiene, though the skin is routinely protected with aluminum paste or similar protective agents as well. The use of the sump drain also permits accurate collection of all drainage which can then be refed, or the equivalent fluid and electrolyte content can be replaced by other means. Ingestion of an adequate diet by mouth is an important feature in treatment of these problems. Welch (13) has recommended treatment of major lateral fistulas by a limited resection of the stomach and placement of a tube in the duodenal stump, reconstituting gastrointestinal continuity by gastrojejunostomy in the usual manner. This procedure will convert the "lateral type" fistula into an "end type" fistula which almost invariably closes and is much easier to handle. An alternative method of handling this problem which has been utilized consists of passing a small feeding tube through the nose allowing it to pass through the stomach, duodenum, and into the jejunum. A second tube for aspiration is placed in the stomach or into the proximal portion of the duodenum. In this manner the fistula can be protected from passage of food and gastrointestinal contents. Adequate nutrition may be obtained by feedings through the small tube passed further into the gastrointestinal tract (11).

A study of the causes of death in this series indicates that the duodenal wounds have the same pattern as observed in wounds of other intra-abdominal viscera, namely that injury to the duodenum alone can almost invariably be handled satisfactorily with a minimum of morbidity and mortality for there were no deaths in patients with injury limited to the duodenum. It is the patient with multiple injuries, particularly injuries to major vessels, that continues to constitute the greatest risk. Because of the close association of the duodenum to major vessels and other organs a high incidence of associated injuries can be anticipated. However, in this series the overall mortality rate of 23 per cent was better than that recorded in most previous reports (3, 9) and in comparing the results obtained in the first 50 cases with the last 36 cases some improvement in mortality was found, being 28 per cent in the first 50 cases and only 17 per cent in the last 36. The primary factor influencing the difference in the mortality rate in the 2 periods was better control of infection rather than more adequate surgical management of the specific injuries encountered. Serious hemorrhage is still attended with a high mortality rate despite the availability of large amounts of blood and technics which have been developed to repair defects in major vessels. Thus, in the future treatment of duodenal wounds, improvements in management of the critically injured patient will be of more significance than improvement in specific technics of handling the duodenal wound.

SUMMARY

The clinical problems presented by 86 patients sustaining wounds to the duodenum were reviewed. The method of duodenal repair depended upon the pathology encountered at the time of operation. In most instances simple duodenorrhaphy was used, though, in patients with complete transection, end-to-end anastomosis between the stomach or jejunum and duodenum was necessary. The mortality rate of 23 per cent represents an improvement over mortality rates previously presented, but still reflects the serious problem of multiple injuries to the abdomen. Most deaths were due to shock, hemorrhage and renal failure. The duodenal injury itself was the cause of death in only one patient.

BIBLIOGRAPHY

1. Albright, H. L. and Leonard, F. C.: Duodenal fistula—problems in management. Ann. Surg., **132:** 49–63, 1950.
2. Bartlett, M. K., and Lowell, W. H.: Acute post-operative duodenal fistula. N. England J. M., **218:** 587–594, 1938.
3. Cave, W. H.: Duodenal injuries. Am. J. Surg., **72:** 26–31, 1946.
4. Cohn, I., Jr., Hawthorne, H. R., and Frobese, A. S.: Retroperitoneal rupture of the duodenum in nonpenetrating abdominal trauma. Am. J. Surg., **84:** 293–301, 1952.
5. Hanley, J. A.: Retroperitoneal duodenal rupture. Brit. Med. J., **1:** 505–506, 1958.
6. Lee, B. G.: Medical Dept., U. S. Army in World War. Vol. 11. Surgery, Part 1. p. 443. Washington, D. C.: United States Government Printing Office, 1927.
7. Miller, R. T.: Retroperitoneal rupture of the duodenum by blunt force. Ann. Surg., **64:** 550–578, 1916.
8. Patton, Thomas B.: Duodenal injury due to nonpenetrating abdominal trauma. Amer. Surgeon, **23:** 587–593, 1957.
9. Sako, Y., Artz, C. P., Howard, J. M., Bronwell, A. W., and Inui, F. K.: A survey of evacuation, resuscitation, and mortality in a forward surgical hospital. Surgery, **37:** 602–611, 1955.
10. Siler, Vinton E.: Management of rupture of the duodenum due to violence. Amer. J. Surg., **78:** 715–729, 1959.
11. Smith, Donald and Lee, Robert: Nutritional management in duodenal fistula. Surg., Gyn. and Obst., **103:** 665–675, 1956.
12. Webb, H. Warner, Howard, John M., Jordan, George L., and Vowles, Keith D. J.: Surgical experiences in the treatment of duodenal injuries. Surg., Gyn. and Obst., **106:** 105–114, 1958.
13. Welch, C. E.: Personal communication.

DISCUSSION

Dr. I. S. Ravdin (Philadelphia, Pennsylvania): I am delighted to have been given the opportunity to have heard these papers and then to open the discussion of them, for they concern injuries that are sequelae of intra-abdominal trauma, and yet they are very closely related etiologically. Dr. Dunphy and his associates have discussed a very rare lesion. It is important that cases in this category be reported following diagnosis by operation or autopsy. Bile aspirated from the peritoneum following trauma is most frequently due to hepatic injury, not to ductal injury or to injury of the gallbladder. It is said that ductal injury is more frequently encountered in children, especially those under the age of five.

Partial severance of the ducts has been more common than complete severance, as related by the authors of the paper this morning.

Dr. Burrus and his associates have discussed an unusual lesion, especially if one excludes penetrating injury by arms. They have pointed out that the high mortality often encountered is due to additional injury sustained by the patient rather than by the duodenal injury itself. This is true for all of the injuries that have been discussed this morning. Duodenal injury does occur following blunt trauma, as does extensive pancreatic injury and, in fact, severance of the pancreas, but these lesions are the most uncommon of the three portions of the small intestine. They are frequently overlooked, even when due to penetrating injuries.

In all of these lesions it is of the greatest importance that exploration be done as promptly as possible; that the circulation be supported by adequate blood replacement; that the exploratory incision be thoroughly adequate in size to permit of extensive exploration, for the patient all too frequently dies following closure of the wound when other injuries have not been diagnosed, found and treated; and that anesthesia be of the best.

This is not an area for neophyte surgeons, or for residents in the early period of their training, although it all too frequently falls to their lot to do this work. We should all think about this and do something about it.

Dr. George L. Jordan, Jr. (Houston, Texas): First I would like to tell Dr. Fletcher that we can add one case of complete transection of the common duct to his collected series. This was encountered in association with a duodenal injury, and the common duct transection was repaired by end-to-end suture. There were no complications related to the treatment of the common duct injury or to the duodenal injury, but the patient died from associated injuries on the fifth postoperative day.

We were very pleased that three of the four patients who developed lateral duodenal fistulas did survive. Each was treated non-operatively with sump drainage and aspiration of gastric contents through a naso-gastric tube. Spontaneous closure occurred. Unless these fistulas close rapidly, jejunal feedings can be performed by passing a small polyethylene tube beyond the fistula, or feeding can be accomplished through a feeding jejunostomy. Dr. Welch, of Boston, has suggested an intriguing method for handling lateral fistulas when surgical intervention is necessary. He has recommended converting the "lateral" duodenal fistula to an "end" fistula by performing a limited gastrectomy and placing a duodenostomy tube into the duodenum. Gastrointestinal continuity is re-established by an end-to-side gastrojejunostomy as usual. We have not utilized this procedure but it may be of value in certain difficult problems.

The mortality rate following duodenal wounds has certainly decreased in the past decade. One hundred years ago it approximated 100 per cent. During World War II there was some improvement with mortality rates of 50 to 60 per cent being reported. In our own institution, improvement in mortality rates has continued. In the first 50 cases reviewed, the mortality rate was 28 per cent, while in the last 36 cases it dropped to 17 per cent. As previously mentioned, the duodenal injury itself has not been the major problem. That problem alluded to by Dr. Ravdin, namely the total care of the patient with severe injury, constitutes the primary problem and it is only with improvement in total patient care that we will further reduce the mortality rate.

TRAUMATIC RUPTURE OF THE EXTRA HEPATIC BILIARY DUCTS FROM EXTERNAL TRAUMA

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INTRODUCTION

Traumatic rupture of the extra hepatic biliary ducts from non-penetrating trauma occurs infrequently. It presents a characteristic clinical picture, which if recognized, can lead to early diagnosis and treatment.

HISTORY

In reviewing Rudberg's original article in German in 1921 (14), there are in addition to his own case, a total of twenty-three cases collected by him from four authors. These were as follows: Lewerentz, 1903 (13 cases); Meissner, 1907 (8 cases); Lepourte, 1913 (1 case); Waugh, 1916 (1 case). Fourteen of these were injuries to the common duct, seven to the hepatic ducts, one to the cystic duct and two in an undetermined site.

Since 1921, nineteen cases have been reported in the literature (1–13, 15–18). Including the additional case reported at this time, it brings the total to forty-five reported cases in the literature since the beginning of the twentieth century. Table I gives a brief summary of these cases, and is presented as a reference guide to the forty-four cases. It is of interest to note that on the average, 13 days elapsed between injury and operation. It is hoped that this paper will help to bring this entity to the minds of physicians so that earlier diagnosis can be made and treatment instituted.

CASE REPORT

Mr. E. P., a 39 year old colored male cook, was admitted to Mount Alto Veterans Hospital on the 28th of June, 1958. The chief complaint was that of abdominal pain; colicky in nature and diffuse, without radiation or referral.

One week prior to admission, the patient was assaulted with blows to the head and epigastrium; the latter "knocked him out". He had regained consciousness shortly thereafter and developed diffuse abdominal pain. The pain persisted and the patient was seen five days prior to admission in the Emergency Room of a local hospital, and was treated with analgesics for relief of diffuse abdominal pain. Three days prior to admission, he developed abdominal distention with emesis which was followed a day later by acholic stools and tea colored urine. He was able to pass flatus freely and had a gray bowel movement the day of admission.

Past history and review of systems were non-contributory.

Physical examination on admission revealed a mal-nourished colored male looking older than his stated age; alert, cooperative, but in moderate distress. Mild scleral icterus was noted. There was ecchymosis over the left eye. The abdomen was moderately distended, soft, and compressible with moderate tender-

TABLE I

A brief summary and reference guide to the 44 cases of traumatic rupture of the extra hepatic biliary ducts from external trauma since the beginning of the 20th century

Author	Patient	Type and Agent of Injury	No. of Days Betw. Inj. & Oper.	No. of Hosp. Days	Operative Findings	Operative Procedure	Outcome
Rudberg, H. 1903–1921, Review of 24 cases		Blows with blunt instruments, being run over or kicked			Rent or transection of: Common duct—14 Hepatic duct—7 Cystic duct—1 Undetermined site—2	Drainage of abdomen—19 Cholecystostomy and cholecystoduodenostomy—2 Treatment unknown—3	5 common ducts, 2 hepatic ducts, 1 cystic duct lived. 11 died. 1 lived 1 died 3 died
Rudbert, H. 1921, Germany	48 y. o. male	Hoof kick to the abdomen	1	1	Rent in the common duct	Drainage of the abdomen	Patient recovered. Follow-up period four years
Anderson, L. 1925, Sweden	44 y. o. male	Fell off ladder and struck in abdomen by a 75 Kg. door	15	15	Bile in peritoneum. Incomplete hepatic or common duct tear	Drainage of abdomen	Patient lived. Follow-up period unknown
Just, E. 1926, Austria	18 y. o. female	Run over by a wagon wheel, upper abdomen	0	0	Ruptured spleen, lacerated liver, lacerated pancreas, complete transection common duct just above pancreas	Common duct primary repair using stent. Drainage of abdomen	Died 15 weeks post-operative
LeClere, G. 1926, France	15 y. o. male	Blow to abdomen by a chain mechanism	25	24	Cystic mass right upper quadrant contained bile. Fracture base skull, right humerus and femur	Marsupialization of cyst and drainage of abdomen	Patient recovered. Follow-up period three months

Wallace, S. et al. 1926, England	47 y. o. male	Crushing trauma to right upper quadrant by two automobiles	11	11	Post mortem: 1. Tear in hepatic duct 2. Several small tears of liver	None—patient died after abdomen was opened	Patient died at operation
Long, L. 1926, U.S.A.	40 y. o. male	Crushing trauma to right upper quadrant by two automobiles	8	2	Tear in hepatic duct near junction with liver	Cholecystostomy. Drainage of abdomen	Patient recovered. Follow-up period unreported
Edington, G. 1933, England	24 y. o. male	Blow to right upper quadrant by man's head	30	12	1st operation: Bile in lesser sac 2nd operation: 33 days later. Fistulous tract to common duct	1st operation: Packing and drainage of abdomen 2nd operation: Anastomosis of fistulous tract to stomach	Patient recovered. Follow-up period unreported
Lewis, K. M. 1938, U.S.A.	49 y. o. male	Crushing trauma by two trucks	11	9	1st operation: Tear in hepatic duct 2nd operation: 5 months later 1) Scarring of common hepatic duct 2) Marked fibrosis, right upper quadrant	1st operation: Drainage of abdomen 2nd operation: Drainage of abdomen; no duct repair due to scar tissue	Follow-up period six years. Biliary drainage two times/week
Lysaght, A. 1939, England	37 y. o. male	Crushing trauma by steel rafter and girders	0	0	Complete transection of common duct, tear in duodenum	Ligation of proximal end of common duct; cholecystogastrostomy	Patient recovered. Follow-up period unreported
Hicken, N. et al. 1948, U.S.A.	7 y. o. male	Crushing trauma to right upper quadrant by tractor hitch	15	4	Tear in common duct	Drainage of abdomen	Patient recovered. Follow-up period ten months

TABLE 1 (*cont'd*)

Author	Patient	Type and Agent of Injury	No. of Days Betw. Inj. & Oper.	No. of Hosp. Days	Operative Findings	Operative Procedure	Outcome
Walker, J. 1953, England	22 m. o. male	Crushing trauma by tractor wheel	40	37	Tear at junction of right and left hepatic ducts	Insertion of polyethylene tube from tear to jejunum; anastomosis of limbs of loop of jejunum	Patient recovered. Follow-up period 16 months
Young, H. B. 1953, England	21 y. o. male	Motorcycle accident	0	0	Tear in common duct extending to include cystic duct	Primary repair of common duct over T-tube	Patient recovered. Follow-up period 16 months
Gross, R. E. 1953, U.S.A.	4 y. o. female	Blow to abdomen by a board	—	—	Tear in hepatic duct	Drainage of abdomen	Patient recovered. Follow-up period unreported
Ibid.	4 y. o. female	Automobile accident	—	—	Transection of common duct	1st operation: Primary repair of common duct 2nd operation: Cholecystoduodenostomy	Patient died 8 years later. Cholangitis Cirrhosis Bleeding varices
Mason, L. B. et al. 1954, U.S.A.	30 mo. o. female	Automobile accident	15	5	Tear in common duct just above pancreas	1st operation: Cholecystostomy and drainage 2nd operation: Cholecystoduodenostomy	Patient recovered. Follow-up period 14 months
Ibid.	6 wk. o. female	"Arbitrarily attributed to trauma even though a positive history is lacking"	44	9	Tear in cystic, hepatic and common ducts	Primary repair of ducts over polyethylene tubing; Cholecystostomy	Patient recovered. Follow-up period six months

Schaer, S. M. et al. 1955, U.S.A.	50 y. o. male	Blow to abdomen by a bull	10	10	Tear in right hepatic duct	Primary repair of hepatic duct over T-tube; drainage of abdomen	Patient recovered. Follow-up period unknown
Mohardt, J. 1956, U.S.A.	28 y. o. male	Automobile accident	0	0	Complete transection of common duct just above pancreas	1st operation: Primary repair of common duct 2nd operation: Cholecystojejunostomy using Roux-y	Patient recovered. Follow-up period two years
Fomon, J. et al. 1956, U.S.A.	34 y. o. male	Automobile accident	4	4	Rupture incomplete of right and left hepatic ducts	Cholecystostomy. Drainage of abdomen	Patient recovered. Follow-up period two years
Donald, J. et al. 1958, U.S.A.	43 y. o. male	Struck in the abdomen by an iron bar	8	8	Rupture complete of the common duct	Primary repair, common duct; Cholecystectomy	Patient recovered. Follow-up period two years

ness in all quadrants. There was no guarding or rebound irritation and peristalsis was hypoactive. The liver and spleen were not felt and there were no masses palpable. On percussion, the abdomen was generally tympanic with shifting dullness present and a fluid wave. Rectal examination revealed gray colored feces, hemotest negative.

Laboratory on admission: WBC 9,400 with 74 neutrophils, 13 stab forms, and 26 lymphocytes, hematocrit 35 vol.%. Chest x-ray dated 6–28–58 showed minimal blunting at the right costophrenic sinus. Survey films of the abdomen showed a moderate amount of gas in the small intestine and some gas in the large intestine with numerous fluid levels in the left upper quadrant.

The total serum bilirubin on the day following admission was 4.05 mgm.%, direct 1.35 mgm.%, indirect 2.70 mgm.%, BUN 28 mgm.%, prothrombin 45% of normal. Total protein 8.30 mgm.%, albumin 4.60 mgm.%, globulin 3.62 mgm.%, sodium 122 mEq., potassium 4.5 mEq., chlorides 463 mgm.%, CO^2 67.2 vol., serum amylase normal. Urinalysis: cloudy, amber colored urine, acid in reaction specific gravity 1.022, 1 + albumin, and a trace of sugar.

Hospital Course: The patient was admitted to the Medical Service for observation, vital signs remaining stable. Over the next three days, the amount of abdominal distention increased and appeared to be greatest with intravenous infusions. The abdominal pain remained unchanged as did the clinical degree of icterus. A peritoneal tap was performed with aspiration of a dark green-yellow fluid which contained bile and was hemotest positive. On 1 July, under pentothal cyclopropane endotracheal anesthesia, the abdomen was opened through a right paramedian incision. The posterior rectus sheath and peritoneum were bile stained. Upon opening the abdominal cavity, 2,500 ccs. of bile was aspirated. Exploration of the abdominal cavity revealed a thick bile covering of all organs. The gallbladder was deflated. Exploration of the porta hepatis revealed transection of the common bile duct just as it passed posteriorly behind the duodenum and pancreas (Fig. 1). The common duct was indurated and narrowed below the entrance of the cystic duct and tapered to a point which would admit only a probe. The common bile duct was probed and found to be patent; there were no stones present. An attempt to insert a #10 French rubber catheter into the free end of the common duct was unsuccessful due to marked narrowing. The common duct was then ligated at the free end and tagged with a black silk suture. A cholecystostomy was performed and the abdomen drained. The patient appeared to tolerate the operation well. Postoperatively the serum bilirubin on 7–2–58 was direct 0.0 mgm.%, indirect 0.3 mgm.%. On 7–5–58 it was direct 1.5 mgm.%, indirect 1.5 mgm.%. The BUN rose to a level of 54 mgm.% on 7–3–58. Culture of the peritoneal fluid, removed at the time of surgery, revealed no organism. Immediately postoperative, the patient was improved except that his urinary output was low for the first twenty-four hours. The abdomen remained distended and there was a productive cough. Chest x-ray on 3 July was normal. One day later, the patient became short of breath, and clinically a diagnosis of bilateral basilar pneumonia was made. Suddenly at 5:00 p.m., after eating a small dinner, the patient expired. Necroscopy revealed the abdominal findings as described

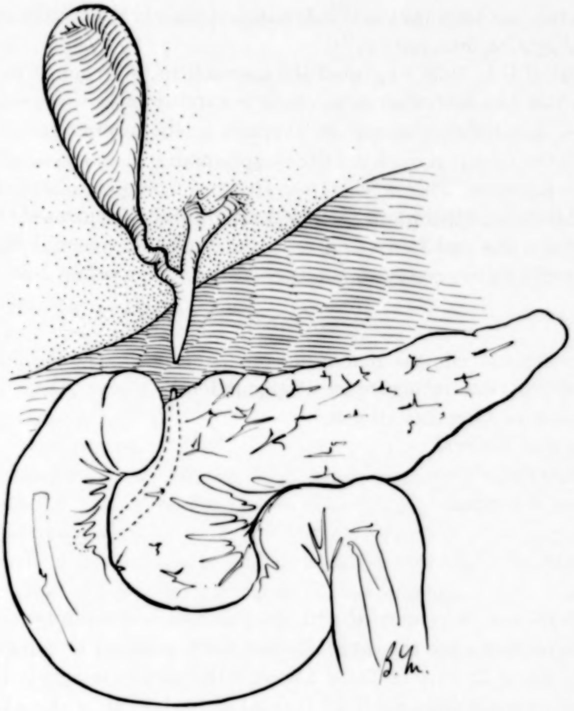

FIG. 1. Transection of the common duct as it passes posteriorly behind the duodenum. It is tapered to a point admitting only a small probe, and the gallbladder is collapsed.

at the operation with still a marked bile peritonitis, and congestive heart failure as the immediate cause of death. This was based on pleural effusion and cor pulmonale. There was minimal bronchopneumonia.

PATHOGENESIS

Traumatic rupture of the extrahepatic biliary ducts, as noted from review of Table I, is caused by nonpenetrating injury to the right upper quadrant of the abdomen, as encountered in acute accidents, crushing injuries and blows to the abdomen.

The exact mechanism of injury to the biliary ducts remains unknown. The following three mechanisms have been suggested and are listed below, with the objections to each one.

1. Lewis (9) in 1958 suggested the mechanism was one of the biliary ducts being impinged on the vertebral column. The objection to this has been that there is minimal associated injury to the abdominal wall.

2. Mason (12) in 1954 suggested that compression of the gallbladder with a sudden increase in the intraductal pressure may play a part in the rupture. The

objection to this has been that in compression of the normal biliary tree, rupture of the ductal system does not occur.

3. Mohardt (13) in 1956 suggested the mechanism to be one of avulsion. The objection to this has been that in incomplete rupture of the common and other biliary ducts, it is difficult to explain avulsion as the mechanism.

Injuries to the common duct usually occur where it passes behind the duodenum and the pancreas. This is where the free and fixed portions of the common duct meet. Likewise, ruptures of the duodenum usually occur at the ligament of Trietz where the free and fixed portions of the duodenum meet. A similar mechanism is thought to be present in ruptures of the common bile duct.

DIAGNOSIS

The characteristic clinical manifestations are:

1. History of non-penetrating injury to the abdomen.
2. Brief period of unconsciousness.
3. Symptom free interval.
4. Diffuse abdominal pain.
5. Abdominal distention.
6. Jaundice.
7. Acholic stools.
8. Cachexia.

The diagnosis can be confirmed with paracentesis and aspiration of bile. The clinical manifestations are the same whether there is a rent or complete rupture of the biliary ducts. Review of Table I reveals the patient is usually not properly diagnosed or operated upon until an average of 13 days after the injury. On the average, seven of the thirteen days were spent in the hospital.

At the time of injury, bile leaks into the abdominal cavity. The bile is sterile and unless it becomes secondarily infected, it causes a clinical picture only of intra-abdominal effusion (13). In addition, fluid is drawn by the bile from the peritoneal and intestinal tissues.

The original period of shock is due to the initial escape of bile into the abdominal cavity. The symptom free interval continues until the quantity of bile becomes great enough to give rise to diffuse abdominal pain and distention. Jaundice ensues from the 1st to the 14th day, the average being the 3rd day (17).

TREATMENT

The Treatment depends on the type and location of the injury to the biliary ducts. It also depends upon the time elapsed between the injury and the operation. For example, primary repair of the ducts can more easily be accomplished in the first few days than later in the disease process. Ductal injuries are best treated by draining the damaged area and possibly the biliary system. If a duct is completely severed, primary repair should be attempted or a short circuiting procedure performed. Stricture after primary repair sometimes necessitates a secondary short circuiting operation. If primary repair cannot be performed, a cholecystostomy or a short circuiting operation can be done.

The various forms of therapy which can be employed are listed below in outline form.

- I. Treatment of injuries to the common duct
    - A. Incomplete rupture
        - 1. Primary repair and drainage of the abdomen.
        - 2. Drainage of the abdomen.
    - B. Complete rupture:
        - 1. Primary repair and drainage of the abdomen.
        - 2. Ligation of the common duct and cholecystotomy or cholecystoduodenostomy or cholecystogastrostomy.
        - 3. Drainage of the abdomen.
- II. Treatment of injuries of the hepatic ducts
    - A. Incomplete rupture
        - 1. Primary repair with drainage.
        - 2. Drainage only.
    - B. Complete rupture
        - 1. Primary repair with drainage.
- III. Treatment of injuries to the cystic duct
    - A. Cholecystectomy
- IV. Treatment of injuries where the site is not determined
    - A. Operative cholangiogram and indicated surgery.
    - B. Drainage.

The earlier the diagnosis and treatment, the more successful will be the outcome.

DISCUSSION

If the diagnosis is kept in mind, it presents a characteristic clinical picture which can be confirmed by early peritoneal tap. The use of intravenous excretory cholangiography may also prove of value. The treatment is early operation with adequate drainage and decompression of the biliary tract. The exact operative procedure will vary with the location, the extent of the trauma to the biliary tract, and the elapsed time. In complete severance of the common duct after 10 days, it appears that due to the narrowing and induration present, primary repair of the common duct is not feasible and that a cholecystostomy or a short circuiting operation will be the procedure of choice.

It is hoped that this report will stimulate further interest in traumatic rupture of the biliary tract from external trauma, re-acquaint you with the clinical picture and bring about a better understanding of this apparently infrequent condition which will tax the diagnostic ability of the surgeon.

SUMMARY

1. A case of traumatic rupture of the extra hepatic biliary duct from external trauma is presented, together with a review of the literature and a tabular summary of reported cases.

2. The History, Pathogenesis, Diagnosis and Treatment of this infrequently

encountered injury are discussed. Its characteristic clinical features make early diagnosis possible. With early diagnosis and treatment, a more successful outcome can be anticipated.

BIBLIOGRAPHY

1. Anderson, L.: Kasuistischer Beitrag zur Kenntnis der subkutanen Leber- und Gallengangverletzungen. Acta chirurgica Scandinavica, **59:** 380, 1925.
2. Donald, J. W., and J. G. Donald: Complete Severance of the Common Bile Duct Due to Non-Penetrating Trauma. Ann. Surg., **148:** 855, 1958.
3. Edington, G. H.: Traumatic Rupture of Bile-Ducts: Drained: Cholefistulogastrostomy, Brit. J. Surg., **20:** 679, 1933.
4. Fomon, J. J., and J. R. Hinshaw: Rupture of The Hepatic Ducts Due to Blunt Trauma. Surg., **39:** 322, 1956.
5. Gross, R. E.: The Surgery of Infancy and Childhood. W. B. Saunders Company, Philadelphia and London, 1953.
6. Hicken, N. F., and V. L. Stevenson: Traumatic Rupture of the Choledochus Associated with an Acute Hemorrhagic Pancreatitis and a Bile Peritonitis. Ann. Surg., **128:** 1178, 1948.
7. Just, E.: Uber einen fall von subcutaner totaler choledochusruptur. Arch. fur. Klin. Chir., **140:** 518, 1926.
8. LeClerc, G.: Rupture Traumatiques des voies biliares. Cholépéritoine. Localisé; Intervention: Guérison. Bull. et Mém. Soc. Nat. de Chir., **52:** 1208, 1926.
9. Lewis, K. M.: Traumatic Rupture of the Bile Ducts. Ann. Surg., **108:** 237, 1938.
10. Long, L.: Traumatic Rupture of the Bile Ducts. South. M. J., **22:** 236, 1929.
11. Lysaght, A. C.: A Case of Traumatic Severance of the Common Bile Duct. Brit. J. Surg., **26:** 646, 1939.
12. Mason, L. B. et al: Rupture of the Extra Hepatic Bile Ducts From Nonpenetrating Trauma. Ann. Surg., **140:** 234, 1954.
12. Mohardt, J.: Traumatic Rupture of the Common Bile Duct; Report of a Case and Review of the Literature. Quarterly Bulletin of Northwestern Univ. Med. School, **30:** 16, 1956.
14. Rudberg, H.: Ein fall von Traumatischer ruptur am ductus choledochus. Munch. Med. Wchnschr., **68:** 1650, 1921.
15. Schaer, S. M. et al: Bile Duct Rupture from External Blunt Trauma. American Journal of Surgery, **89:** 745, 1955.
16. Walker, J. H. M.: Traumatic Rupture of the Bile Duct. Lancet., **265:** 969, 1953.
17. Wallace, S. A., and A. Spiro: Traumatic Rupture of the Hepatic Duct, Brit. J. Surg., **13:** 582, 1926.
18. Young, H. B.: Traumatic Rupture of the Bile Ducts. Lancet., **265:** 1262, 1953.

CONSERVATIVE TREATMENT OF OLD FRACTURES OF THE CARPAL SCAPHOID

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Don't throw away the cast.

Fractures of the scaphoid were seldom recognized prior to the advent of roentgenography. Stimson, professor of surgery at Cornell University at the turn of the century, said that simple fractures of this bone were rare, and disability the usual outcome. Even after the X-ray had made accurate diagnosis possible in most instances, the treatment of this fracture has been characterized by varying and imperfect techniques, frequently resulting in nonunion for the following reasons:

1. Failure to recognize the fracture on initial X-ray film.
2. Failure to maintain immobilization until healed.
3. Failure to immobilize in dorsiflexion and radial deviation, and failure to include the proximal phalanx of the thumb.
4. Failure to reduce grossly displaced fragments.

The blood supply to the proximal area is through the nutrient arteries in the mid portion of the bone. (fig. 1). This is often interrupted when fracture occurs. The tubercle has its separate blood supply, but the proximal portion is dependent on the integrity of the bone for nourishment. The site of the fracture, therefore, affects the prognosis. Fractures occur in three general areas: (1) the tuberosity, (2) the waist, and (3) the proximal portion, although they may occur anywhere in the bone. Fractures of the tuberosity rarely present significant displacement. They invariably heal. Fractures across the waist are most numerous. The blood supply to this area is, in general, adequate. Fractures of the proximal portion are prone to develop avascular necrosis, which accounts for many of the late changes in these fractures.

METHOD OF INJURY

Fractures of the carpal scaphoid occur in young people from a fall on the outstretched hand. They are most frequently seen in males between the ages of 20 and 40. They are commonly found in the military service and amongst other physically active people. They are often mistaken for a sprained wrist. The symptoms are pain and limitation of wrist motion. The physical signs are slight swelling on the radial side of the wrist, tenderness distal to the radial styloid in the anatomical snuff box, and indirect tenderness through the first metacarpal

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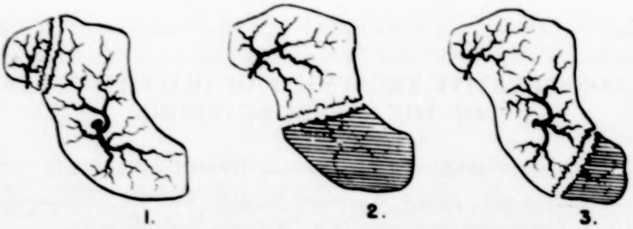

FIG. 1. Blood supply to carpal scaphoid, and fracture sites. 1. Tubercle 2. Waist 3. Proximal pole (By permission Annals of Surgery)

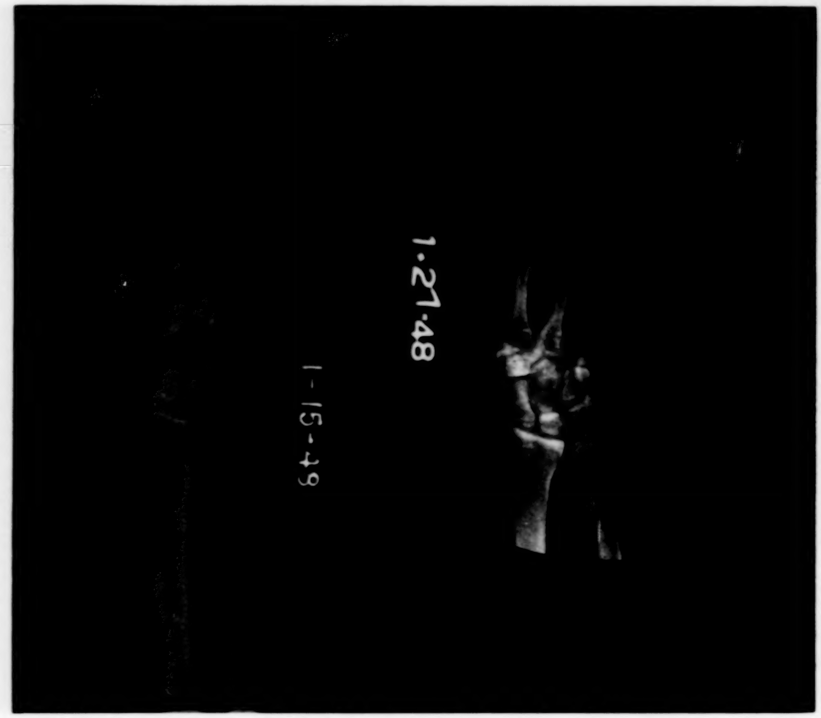

FIG. 2. The fracture line is not seen in the film of 1-15-48 It shows clearly in the film of 1-27-48.

bone. It may be necessary to take several views of the wrist in order to show the fracture early. One must have antero-posterior, lateral, and oblique views. Views in radial and ulnar deviation are also advisable. In one of our patients, the fracture was not recognized on the wet film immediately after injury. (Fig. 2). If there is a fracture clinically, the injury must be treated as a fracture despite negative films. If no fracture line is seen at the time of injury, repeat films in

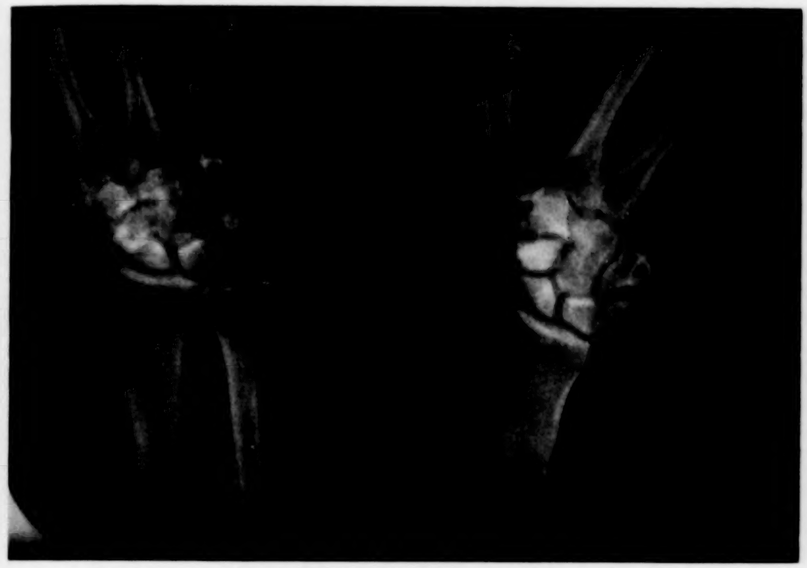

FIG. 3. The fracture line is not seen when the hand is in radial deviation. It is plain in ulnar deviation.

10 to 14 days after absorption has occurred will show the fracture. In another of our patients, a fracture line was readily demonstrated in a film of the wrist taken in ulnar deviation whereas it could not be seen in radial deviation. (Fig. 3).

ASSOCIATED INJURIES

Fracture of the scaphoid may not be an isolated injury. The most commonly encountered associated injuries are:

1. Dislocation of the radio-carpal joint.
2. Dislocation of lunate.
3. Dislocation between the two rows of carpal bones.
4. Fracture of the base of the first metacarpal bone.
5. Fracture of the distal end of the radius.

These complicating conditions must, of course, be promptly and appropriately treated.

X-RAY CHANGES

The possibility of being unable to recognize the fracture on the X-ray film immediately after the injury has been noted above. Absorption at the fracture line is seen within two weeks of injury. This is followed in 6 to 8 weeks by further bone absorption, and the appearance of vacuoles or pseudocysts. These commonly appear earlier in the proximal fragment, and may be confined to this fragment. Further necrosis and perhaps sclerosis of the proximal fragment with smoothing of the fracture surfaces occur within a year. Arthritic spurring of the fracture fragments, pointing of the radial styloid, with narrowing of the joint space and destruction of the adjacent cartilaginous surfaces, indicate longstanding pathology.

TREATMENT

All authorities are in agreement that acute fractures of the carpal scaphoid should be treated by immobilization of the hand in the position of function. (Fig. 4). There is a good deal of disagreement as to how long the immobilization must be maintained. Surprisingly enough, Destot, (2) whose comprehensive monograph is a classic, seemed to think that 10 days was long enough. Grace (4) advocated a period of 6 weeks. Speed (8) thought 7 to 8 weeks was sufficient. Bohler (1), in a contradictory fashion, advocates immobilization for 6 weeks although he says that immobilization should be continued until healing takes place. On occasions fractures of this bone are initially seen by the doctor weeks or months after injury. In other instances healing is not demonstrated after several months in plaster. Such cases are frequently regarded by the surgeon as exhibiting non-union and requiring operation. Numerous operations have been used to promote union of this bone. Each has its proponents, and all have produced union in a greater or lesser percentage of cases. None has uniformly resulted in union.

We are concerned here only with non-operative treatment of these fractures.

NON-INTERFERENCE IN CASES OF NON-UNION

Not all instances of non-union of the carpal scaphoid need active therapy. A good many people who are not manual workers can get along quite happily and

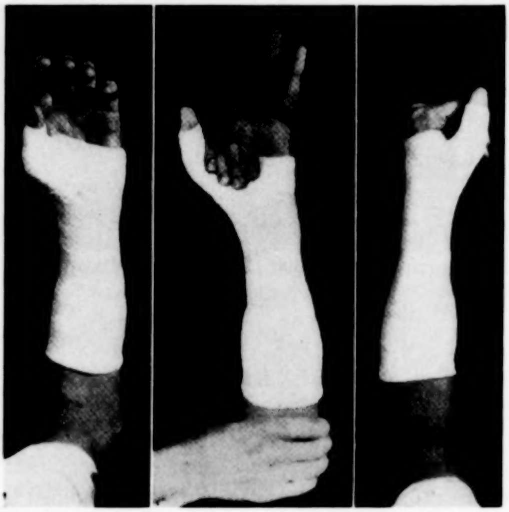

FIG. 4. Fractures of the carpal scaphoid should be immobilized in extension and slight radial deviation. The proximal phalanx of thumb is included.

comfortably without any interference. Speed and Smith (9) have stated that many patients do as well with 9 wrist bones as with 8. Thorndike and Garrey (10) cite a group of 10 patients whose symptoms they believed insufficient to warrant surgery. Seven of these subsequently played college football. Among our patients, 8 with fractures from 12 to 40 years old have carried on with some loss of motion, and pain on hard use, but have led active useful lives.

ANALYSIS OF CASES

We have reviewed 90 carpal scaphoid fractures which have come to our attention in recent years. No case is included which was not examined by one of our staff a year or more after his initial visit. There were 37 acute fractures (up to 2 weeks old), one bilateral. All but one were males.

ACUTE FRACTURES

The period of follow up of the 37 acute fractures varied from 1 to 12 years. The average was 4½ years. There were 3 infractions and 4 fractures of the tubercle in this group. These healed within a few months. Six acute fractures healed within a period of 6 months; in three, the length of time of immobilization was not recorded. A total of 6 fractures, including two which united within a 6 months period, healed with some deformity, refuting those who believe it is necessary to open every case with displacement of fragments. Fourteen acute fractures united after immobilization between six and twelve months. Nonunion developed in four patients. One had only two, one three, and one four months of immobilization. The time of immobilization in the other was not determined.

SUB-ACUTE FRACTURES

Three men were seen initially between 2 weeks and 6 months after injury. In one of these a Murray (6) type bone graft was done 6 months post-trauma. Healing resulted. One was immobilized for only 3 months. Eleven years later, there was a nonunion. One patient was hospitalized 3 months after his scaphoid fracture with a fracture of the femur. The wrist injury was not mentioned and no X-ray was taken at time of admission. The scaphoid fracture healed along with the femur while he was at bed rest.

OLD FRACTURES

There were 50 old fractures varying in age between 6 months and 40 years. There was one each, 40 years, 37 years, 34 years, 25 years, and 20 years old. The pathology and therapy in this group varied greatly.

In four of these cases, displacement of fragments was evident on the first visit to us, and may have been a factor in the non-union. One was the 40 year old fracture; two were 8 years old. In one, the age is uncertain. We do not know the nature of the original treatment of these patients.

Among the undisplaced fractures 18 instances of non-union could be attributed primarily to inadequate immobilization. There was no immobilization in 8 cases. There was 4 months or less in 7 cases; there was 6 to 9 months immobilization in 3 cases.

Five old fractures healed following prolonged immobilization.

In 1934, Soto-Hall and Haldeman (7) emphasized two factors in treatment: 1) Immobilization must be complete and must be maintained until healing occurs. 2) Immobilization is best obtained by placing the wrist in dorsiflexion and radial deviation, and by including the thumb in the plaster. With the passage of time, it has been realized that prolonged immobilization is frequently necessary to secure union. In 1940, Thorndike and Garrey (10) reported union in 5 of 6 fractures immobilized between 12 and 16 weeks. More recent studies emphasize this necessity for long immobilization. Dickison and Shannon (3) in 1944 stated that of 116 carpal scaphoid fractures without displacement, 82 united within 5 months, and the remainder within 9 months. Wagner (11) in 1952 reported union in 14 fractures of the scaphoid, the average period of immobilization of which was 11 months. No time limit for the immobilization of fresh fractures can be arbitrarily adopted.

Agreement on the optimum treatment of old non-united fractures is lacking. If there is no marked sclerosis of the proximal fragment, and if the fragments are in good position, immobilization is probably the treatment of choice even though these fractures are a year or more old. Luxardo (5) reviewed 190 cases of fractures of the carpal scaphoid from the Argentine Army in 1956. He reports union of a 450 day old fracture of the wrist after plaster immobilization of 210 days, and he had an equally fortuitous result in a 360 day old fracture immobilized for 180 days.

CASE REPORTS

M. F. A twenty-four year old wrecker injured his right wrist in a toboggan accident eight months prior to his initial visit in February 1950. He had an ununited fracture of the proximal pole. The wrist was immobilized in plaster 12 months, and he wore a gauntlet for 2 additional months. The fracture line was barely discernible by X-ray at the end of that time. Reexamination two and a half, and six and a half years following his initial visit showed complete healing by X-ray. He was working regularly and had full painless motion of the wrist (Fig. 5).

A. L. A 38 year old housewife fell in March 1950, injuring her left wrist. Fifteen months later she came in with a fracture of the waist which showed a considerable gap between fragments, but no sclerosis or arthritis. She was immobilized in plaster for 22 months, at the end of which time there was clinical union. She was last seen 6 and a half years after injury. There was full, painless wrist motion, and no evidence of fractures in X-ray film. (Fig. 6).

N. R. An 18 year old student hurt his right wrist in September 1953, playing football. Eleven months later he presented himself with a fracture of the waist with some vacuolization of the distal fragment, but no sclerosis or arthritis. After 6 months' immobilization there was clinical union and X-ray showed complete bony regenerations.

F. F. An 18 year old student fell on the outstretched left hand in October 1950. He was initially seen 13 months later. There was a transverse fracture through

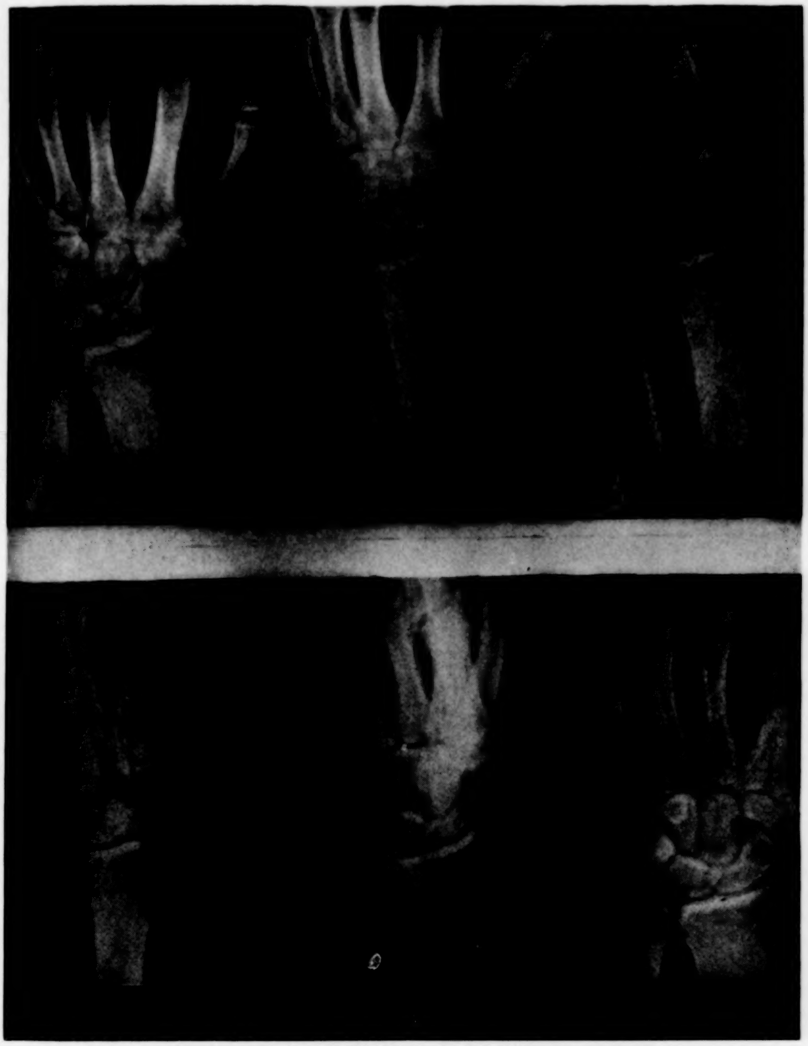

FIG. 5. Top, nonunion of scaphoid 8 months post trauma. Bottom, 2 years later union is shown.

the waist, with a little vacuolization of distal fragment, no sclerosis and no arthritis. Following 11 months in plaster the wrist was clinically solid, and the fracture line had largely disappeared on X-ray. X-rays 3 years, and six and a half years post immobilization show complete regeneration of the bone. The man had full painless function. (Fig. 7).

J. Y. A 42 year old motion picture actor fell from a boxcar on 6 August 1955,

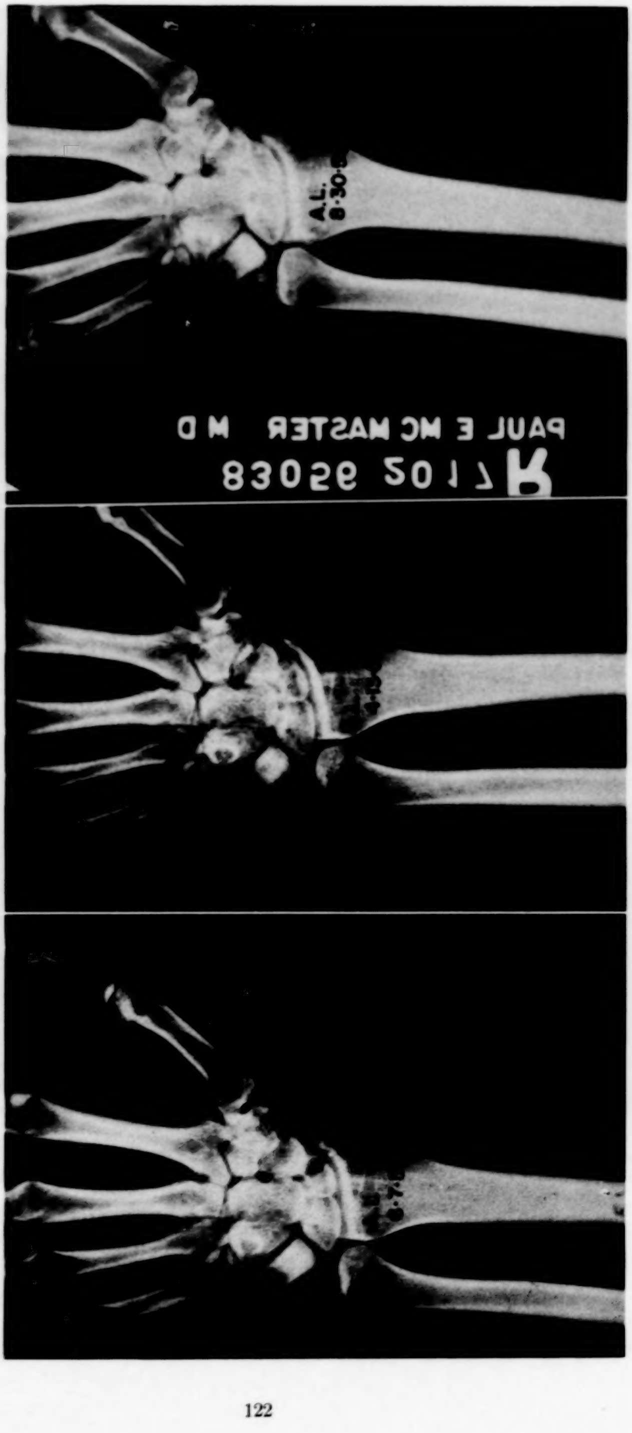
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FIG. 6. Left, nonunion of scaphoid fifteen months post-injury. Middle, union after twenty-two months' immobilization. Right, three years later, six years post trauma, fracture remains healed.

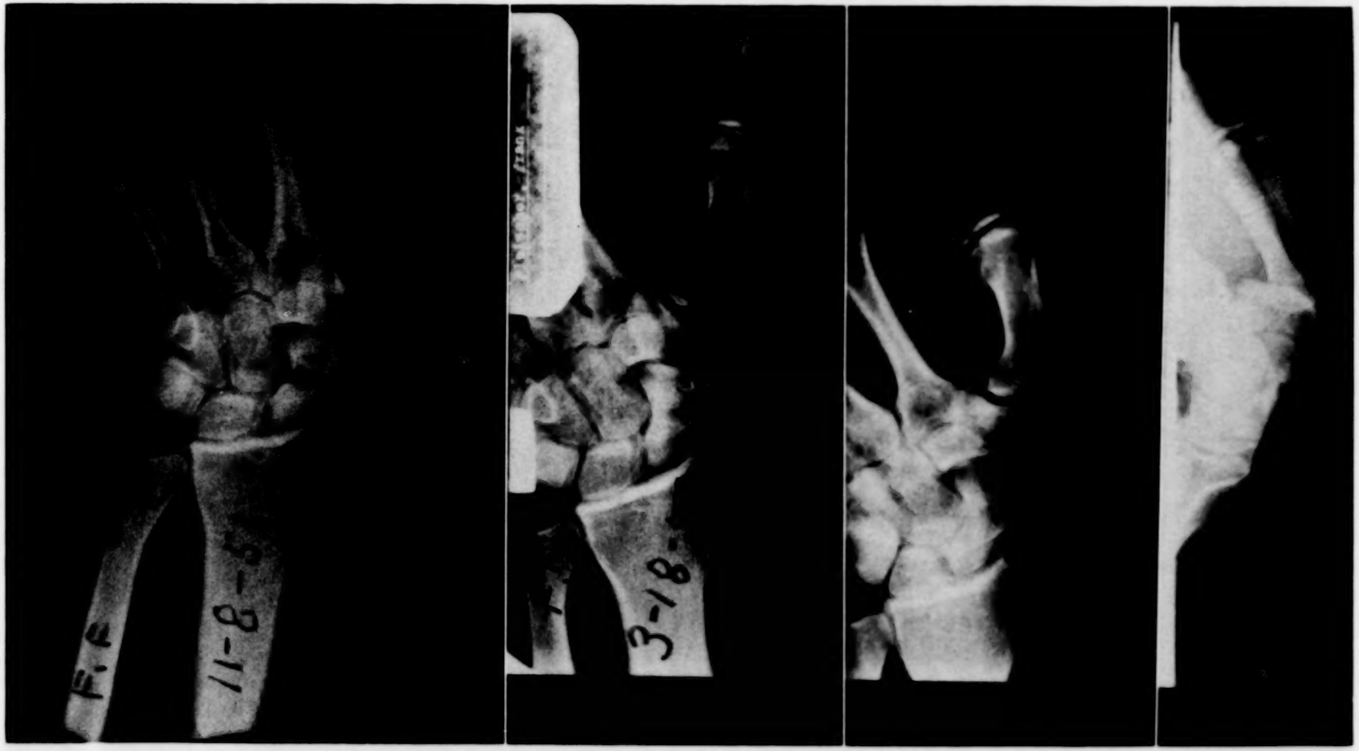

FIG. 7. Left, nonunion of scaphoid thirteen months post trauma. Right, six and one half years later the fracture is healed.

injuring his left wrist. It was regarded as a sprain. He fell on the left hand again 6 months later, after which there was increased soreness of the wrist, but he did not see a doctor until 8 months from the time of the original injury. At this time X-ray showed a fracture across the waist, with considerable absorption in the fracture line, without gross displacement, vacuolization, sclerosis, or arthritis. He was immobilized in position of function for 10 months. At the end of that time there was clinical and X-ray union. He was last seen 2 years following release from plaster. There was a full range of motion and X-ray showed no evidence of the fracture.

DISCUSSION

The 5 fractures which healed following prolonged immobilization exhibited several similarities. They occurred in relatively young, healthy people. They had all been diagnosed initially as sprains of the wrist. They had, therefore, not been immobilized primarily.

X-ray findings showed absorption at fracture line, sometimes vacuolization, no sclerosis of fragments, no arthritic spurring or narrowing of joint, and no gross displacement of fragments.

We concede that there are instances in which operative interference for fractures of the carpal scaphoid is indicated. These are, 1) in acute fractures, where reduction of accompanying dislocations cannot be accomplished by manipulation alone. 2) In acute fractures with gross displacement of fragments. 3) In old, well established non-unions where pain in wrist interferes with earning a living.

Not all non-unions need an operation. Many people carry on nicely with their non-unions.

SUMMARY

Five patients whose carpal scaphoid fractures were 8 to 15 months old secured union following prolonged plaster immobilization of the wrist and thumb. Fresh fractures of the carpal scaphoid without gross displacement should be immobilized in the position of function until union occurs.

Old fractures without gross displacement, sclerosis of fragments, and arthritic changes, should likewise be immobilized until union occurs.

Don't throw away the cast.

ACKNOWLEDGEMENT

We wish to thank Dr. Fred W. Ilfeld and Dr. Paul E. McMaster of Beverly Hills for permission to include two of their private patients in this review.

REFERENCES

1. Bohler, L. The Treatment of Fractures, 5th ed. Grune and Stratton, Inc., New York, 1956.
2. Destot, E. (Translated by F. R. B. Atkinson). Injuries of the Wrist. Paul Hoeber, New York, 1926.
3. Dickison, J. C. and Shannon, J. G. Fractures of the carpal scaphoid. Surg., Gynec. & Obst., **78:** 83, 1944.

4. Grace, R. V. Fractures of the carpal scaphoid. Ann. Surg., **89:** 752, 1929.
5. Luxardo, J. C. Consideraciones Sobre Ciento-Noventa Fracturas de Escafoides Carpiano. Rev. san. mil., Buenos Aires, **55:** 420, 1956.
6. Murray, G. Bone graft for nonunion of the carpal scaphoid. Brit. J. Surg., **22:** 3, 1935.
7. Soto-Hall, R. and Holdeman, K. O. Treatment of fractures of the carpal-scaphoid. J. Bone & Joint Surg., **16:** 822, 1934.
8. Speed, K. Small bone repair. Surg., Gynec. & Obst., **64:** 9, 1937.
9. Speed, J. S. and Knight, R. A. Campbell's Operative Orthopaedics, 3rd. ed. C. V. Mosby Co., St. Louis, 1956.
10. Thorndike, A. and Garrey, W. E. Fractures of the carpal scaphoid. New England J. Med., **222:** 827, 1940.
11. Wagner, C. J. Fractures of the carpal-scaphoid, J. Bone & Joint Surg., **34A:** 774, 1952.

DISCUSSION

Dr. D. W. Gordon Murray (Toronto, Ontario): I am much interested in this paper and would like to congratulate the speaker on his presentation. He has presented a very faithful picture of the problems related to such injuries, and what I have to say is not in any way to quibble but to step into that small place left by Dr. Mazet where he said there was a small nidus where somebody else might have something to say. Well, I'm that small nidus, and what I have to say is to supplement and point out from my point of view that there may be other methods of doing these things. All I will do is give you my results.

(Slide) This is the sort of a wrist that we all want to avoid.

(Slide) This is one we are trying to prevent, and my interest was stirred because of so many late results of this nature.

(Slide) This is just to show, in addition to Dr. Mazet's slides, the scaphoid with its ligamentous attachments, through which comes the blood supply. The aseptic necrosis in such problems so well described by Dr. Mazet results from injury leaving portions of the bone without blood supply.

(Slide) This is to show, and my efforts will be to support a claim for, bone grafting of the scaphoid. When it should be done is important; certainly it is not for wrists such as we saw in the first two slides. If there is extensive arthritis or much aseptic necrosis, it is not suitable. But most of my people have been young workmen, strong men who were hurt at work, so strong that their bones are tough enough that they do not get a Colles' fracture, which would occur in the older people. And to those people loss of time is tremendously important.

So, if a man has a fracture of his scaphoid, if after three or four months' splinting it is not united or showing signs of union, I think he should be bone grafted. In slightly over 260 that I have done we have had them back to work on the average in four months, without disability and 96 per cent union with good results. Those people are very grateful for having a good, strong, tough wrist, and what I will show you now are the late results of some of these.

(Slide) That is a bone graft of the scaphoid 13 years after it was done. You can see the graft is so well incorporated it is hard to identify it. This is the first one I did, in 1933.

(Slide) This is 25 years after bone grafting of the scaphoid. I think if he fell he would break his other one before he would break that one again.

(Slide) This is a mid-carpal dislocation with scaphoid fracture. Referring to the second paper, my inclination is to do an open reduction on them all, and I think the key to the situation, when you have the reduction, is to put a bone graft in the scaphoid. Of course that's my weakness, but I would recommend it, as it does give a good result.

(Slide) There is a lateral view of such a situation.

(Slide) There is the reduction. This was done four months after the thing had been missed. It was grafted, and (slide) this is 13 years later. You can see his wrist joint and the grafted scaphoid. He may have a little arthritis, but he is a hard worker and has a good wrist.

(Slide) These two following are in very critical observers. This is Dr. K. He is a nose and throat surgeon, who works regularly at his job. He had a fractured scaphoid and was disabled with the pain in his wrist. Everybody advised against doing it because of the arthritic changes and some necrosis of this fragment. But, explaining all this, we undertook it. This slide is about ten years later. He does his work and is very pleased with his wrist.

(Slide) The next one is another doctor, Dr. S., a surgeon. He also is very pleased with the result on his wrist. My only contribution is to suggest that as an alternative method, bone grafting is worthy of considerations.

DR. HARRISON L. MCLAUGHLIN (New York, New York): One cannot quarrel with Dr. Mazet's thesis that many fractures of the carpal scaphoid will unite if immobilized well and long enough. He has prudently pointed out that not all such fractures will heal under this treatment and that faulty union is not always productive of symptoms or disability. It is also true that bony union is not always synonymous with a good wrist.

The obvious implications of his paper raise some questions relative to the treatment of these fractures in civilian practice. The penalties of disablement consequent to immobilization for many months or more are not the same for service personnel as for wage earners. I would hesitate to invite the economic and emotional catastrophes inherent in putting a plumber, a carpenter, or a mechanic out of work for a year or more in order to obtain union in this small bone which, when necessary, can be grafted or excised. I wonder if Dr. Mazet would be willing to give up his operative practice for one or two years in order to obtain union of his own fractured scaphoid.

The question is whether we are to treat a broken bone or an injured person. Dr. Gordon Murray's work leaves little room for doubt that faulty union of the fractured scaphoid can be corrected by bone grafting procedures. Let us fit our treatment of fractures to our patients, not the reverse.

DR. MASON HOHL (Los Angeles, California): We plead only for consideration of this method when the fracture surfaces have not become sclerotic, when the fracture surfaces oppose, and when arthritic change is not present. Cystic change in the fracture area is not important, since healing does occur in these cases. Incidentally, there is nothing to lose by trying this method, except time. Some of our patients have not lost any time from work and, incidentally they are private patients. This method of treatment is consistent with many occupations, since with airtight casts one can even immerse the wrist in water.

How should this method be used in civilian practice? Well, one has to talk to patients, and one has to live with them, especially in a small community. As a surgeon you don't want to do harm. Certainly this method does no harm.

You can tell your patients that you can cure them by Dr. Murray's method, and certainly he can do it in a high percentage of cases. He is a marvelous technician and knows the scaphoid bone graft method well. We apply a navicular cast and often see some evidences of healing within the first cast change time, which is about three months. If it looks agreeable, then we will continue with the method.

There was one other question, about what Dr. Mazet would do in his practice, and I am privileged to answer for him. A surgeon is not generally a heavy worker, even though he may be a surgeon dealing with trauma, fracture reductions, or dealing with fine structures in surgery. Nonunion of a carpal scaphoid fracture may not bother him very much. Dr. Mazet says that he will accept his nonunion.

We hope that you will consider the method in selected cases. We don't mean it as a panacea for every nonunion of carpal scaphoid. It has worked with our few cases. Perhaps each of you will find a suitable case in which the immobilization may be used. We do not wish to discard the bone graft method. We like the Barnard procedure. We have used both and we intend to continue. But think about simple long-term immobilization.

Thank you very much for both of us.

DISPLACED INTRACAPSULAR FRACTURES OF THE NECK OF THE FEMUR

1. Mortality and Morbidity

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The disappointment in results following internal fixation of displaced intracapsular fractures of the femoral neck has led to the widespread use of immediate replacement of the head and neck of the femur with a metallic prosthesis (1–3) for this condition. Ten years has passed since the Judet brothers popularized and gave stimulus to these newer methods. Therefore, it is appropriate, at this time, to reappraise and compare results carefully. Has the insertion of a replacement proven to be a simpler procedure? Has it reduced mortality and morbidity? Has it shortened the hospital stay? In the evaluation of the two methods, it is important that only similar recent injuries be included in the analysis.

This study presents 205 acute, displaced fractures of the femoral neck treated at the New York Orthopaedic-Columbia-Presbyterian Medical Center during the decade between 1949 and 1960. Treatment consisted of open reduction and internal fixation with a Smith-Petersen nail in 105 patients and of early replacement arthroplasty in 100 patients. The sole purpose of this paper is to compare the mortality and morbidity in the two groups, without regard to the end results.

CLINICAL MATERIAL

This was a consecutive series of patients without selection upon whom surgery had been performed by residents and attending surgeons of varying experience. All records and radiographs were reviewed simultaneously by the three authors. Open reduction was done in all but two of the fractures in the internal fixation group and the antero-lateral incision (Watson-Jones) was used (4). The Judet method of replacement arthroplasty was used initially with the insertion being accomplished through the anterior route (5) (23 patients). The stem appliance was later abandoned in favor of the medullary prosthesis (3) (77 patients), table I. Follow-up examinations for six months following surgery were considered adequate for appraising general complications and mortality.

Read before the Twentieth Annual Session of The American Association for the Surgery of Trauma, Coronado, California, October 5–7, 1960.

Discussion of this paper is included with that of the following paper by Drs. Ambrose and McLaughlin.

FINDINGS

Preoperative Condition. The average age of the patients treated by immediate replacement was nearly ten years greater than that of patients treated by internal fixation. These older patients had a greater incidence of medical problems preoperatively, table II. It is necessary in making the comparison to recognize that the older and poorer risk patients had more often been treated with the endoprosthesis. However, when we further analyze the age groupings, table III, we see certain areas, such as in the 70 year to 79 year age category, where direct comparison can be of value.

TABLE I

Surgical Procedures

Internal Fixation		105
Open Reduction	103	
Blind Nailing	2	
Replacement Prosthesis		100
Judet	23	
Austin Moore	77	

TABLE II

Preoperative Condition

	Internal Fixation (105)	Prosthesis (100)
Average Age	66 yrs.	76 yrs.
Diabetes	1	12
Senile Psychosis	4	11
Hemiplegia	3	10
Cataract	0	10
Blind	1	5
Parkinsonism	3	5
Malignancy	2	10
Rheumatoid Arthritis	1	3
Cardiac Failure	3	3
Other Fracture	4	2

TABLE III

Age

	Internal Fixation (105) (Average age 66)	Prosthesis (100) (Average age 76)
Under 40	3	0
40–59	24	4
60–69	31	15
70–79	38	43
80–89	8	38
90–100	1	0

TABLE IV

Interval to Operation

	Internal Fixation	Prosthesis
Under 12 hr.	47	27
12–48 hr.	36	39
Over 48 hr.	22	34

TABLE V

Operating Time

Open Reduction-Internal Fixation (103)	2 hr. 12 min.
Judet Prosthesis (23)	
Anterior	1 hr. 46 min.
Anterolateral	2 hr. 16 min.
Austin Moore (77)	
Anterior	1 hr. 57 min.
Anterolateral	2 hr. 48 min.
Posterior	1 hr. 47 min.

TABLE VI

Postoperative Complications

	Internal Fixation (105)	Prosthesis (100)
Hematoma	2	6
Infection	4 (1 died)	6 (3 died)
General	36%	58%
Mortality	4%	18%

Interval to Operation. The intervals from injury to surgery were similar, table IV, with the exception of a slightly greater trend for delay in the replacement group. Analysis of the categories shown, however, failed to reveal a significant difference in morbidity and mortality in patients operated upon at these various intervals. This is in contrast to a previous report from our Clinic (16) regarding the effect of delay upon patients with displaced intertrochanteric fractures.

Length of Operation. The operating time, as measured from the skin incision to the completion of the skin closure, is shown in table 5. One reason for the antero-lateral approach, requiring more time for prosthesis insertion, was that in each instance where this incision had been used, the surgeon had originally set out to internally fix the fracture and changed his mind after inspecting it. It is striking to note, however, that when one considers the time required for roentgen control of a hip nailing that the average operating time for inserting a prosthesis was very nearly the same as that for open reduction and internal fixation.

Morbidity. General complications are difficult to assess by a quantitative method; however, each complication was discussed by the three authors and the significant problems recorded as shown, table VI. There were twice as many wound complications in the prosthesis group. In addition, it is of note that three of the six patients developing wound infections at the site of prosthesis replacement died. The incidence of general complications in the patients treated by prosthetic replacement also indicates that this procedure is not entirely innocuous. A mortality was considered to be related when death occurred within 30 days following injury and any other death when causes were directly related to the hip fracture, provided death occurred within 6 months. The causes of death are listed in table VII. The fact that the related mortality was four and a half times greater in the patients treated by prosthetic replacement is a most impressive finding. We can further analyze mortality in patients of the eighth decade where

TABLE VII

Causes of Death

	Internal Fixation (4)	Prosthesis (18)
Pulmonary Infarction	1	3
Uremia	—	4
Cerebral Accident	2	3
Pneumonia	—	2
Coronary Occlusion	1	2
Liver Failure	—	1
G.I. Hemorrhage	—	1
Debility and Decubitus	—	2

TABLE VIII

Mortality. Patients Aged 70 to 79 Yrs.

Internal Fixation (38)	Prosthesis (43)
1 (3%)	9 (20%)

TABLE IX

Prosthesis Complications. Approach

	Anterior (45)	Posterior (41)
Infection	5	1
Mortality	13	5

TABLE X

Length of Hospitalization

Internal Fixation	32 Days
Prosthesis	29 Days

comparable numbers were treated by the two methods, table VIII. Again, the difference is striking. Both systemic and wound complications were more frequent when the appliance had been inserted through the anterior route, table IX. It was thought that this was due to greater soft tissue injury and lack of dependent drainage in the case of the anterior wound.

Length of Hospital Stay. The duration of the hospital stay is shown in table X. Whereas one would expect to see a significantly shorter period of hospitalization when the prosthesis had been used because early weight bearing could be permitted, this proved not to be the case. The length of hospital stay was about equal in the two groups.

COMMENTS

This review of the morbidity and mortality of 205 patients with recent injuries has shown that, whereas replacement has a definite place in the treatment of femoral neck fractures, it is clearly not a panacea. The frequent statement that patients treated with a prosthesis are able to leave the hospital sooner has not proven valid. In our Clinic, the mortality has been four and a half times greater in patients treated by prosthesis than in those with internal fixation. The significance of this figure is altered by the fact that the average age of these individuals was 10 years greater and they were frequently in poorer general condition. However, there is no doubt that the insertion of a prosthesis is a procedure of such magnitude as to be unwise in certain frail and poor risk patients. A simple procedure to stabilize the fracture in order to relieve the pain and permit mobilization might be better.

CONCLUSION

The prevalent impression that early insertion of a prosthesis in recent hip fractures is a relatively benign procedure, in the aged patient, is not borne out in this study.

This procedure is of such magnitude as to demand the most critical deliberation before being employed in the poor risk patient.

BIBLIOGRAPHY

1. Mahoney, J. W., Mulholland, J. H., Jahr, J., and Dooling, Capt. J. A. Immediate Moore prosthetic replacement in acute intracapsular fractures. *Am. J. Surg.:* **95,** 577–580, 1957.
2. Campbell, R. D., Jr., Mason, J. S., Wilson, P. D., Jr., and Wade, P. A. The use of intramedullary prosthetic replacement in fractures of the femoral neck. *Am. J. Surg.:* **99,** 745–755, 1960.
3. Moore, A. T. The self locking metal hip prosthesis. *J. Bone & Joint Surg.:* **39A,** 811–827, 1957.
4. Neer, C. S., and McLaughlin, H. L. Intracapsular fractures of the neck of the femur. *Am. J. Surg.:* **LXXVI,** 528–536, 1948.
5. Judet, R. and Judet, J. The use of an artificial femoral head for arthroplasty of the hip joint. *J. Bone & Joint Surg.:* **32B,** 160, 1950.
6. Neer, C. S. The surgical treatment of the fractured hip. *Surg. Clin. N. A.:* **31,** 499–512, 1951.

SLIPPED UPPER FEMORAL EPIPHYSIS AND TRAUMA

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Many adults are crippled because a slipped upper femoral epiphysis was unrecognized or neglected in early adolescence. The symptoms of this condition may be initiated by trauma and the complaining child is not always brought to the attention of a surgeon prepared to provide appropriate care. It is a purpose of this paper to urge that all physicians, especially surgeons interested in trauma, share with the orthopedic surgeon the responsibility for early recognition that is so important to the management of this serious condition.

This proposal is validated by data relative to one hundred consecutive cases treated by surgery at Columbia-Presbyterian Medical Center since 1943 which have been followed from two to ten years with an average of five years subsequent to treatment.

ON THE RELATIONSHIP BETWEEN TRAUMA AND SLIPPED UPPER FEMORAL EPIPHYSIS

35% of these children applied for treatment of symptoms which followed an injury. Both the injury and the symptoms were mild.

It is important to recognize that this condition commences as an idiopathic disease which weakens the epiphyseal connections between the head and neck of the femur. Once established, the femoral head can be displaced by even so minor a trauma as a misstep. The diseased epiphysis is easily recognized in roentgenograms, but the imminence of its disruption defies identification. It is therefore the surgeon's responsibility to see that the affected epiphysis, once recognized, is protected against all traumas including ordinary ambulation until definitive treatment has been implemented. Under such circumstances it has been our policy to urge immediate hospitalization for complete bed rest pending definitive treatment.

An evaluation of the influence of operative trauma and variations of technique chosen is relevant but difficult. It was noted that two femoral heads were raised from the neck by Smith-Petersen nails, but neither developed avascular necrosis in a five year follow-up period.

Some patients have disrupted their fixation, and destroyed their hip by weight bearing prior to healing—others have borne weight without mishap.

Read before the Twentieth Annual Session of The American Association for the Surgery of Trauma, Coronado, California, October 5-7, 1960.

CONCERNING THE DIAGNOSIS

Formerly it was considered that slipped upper femoral epiphyses were not common except in fat white boys about twelve years of age. 30% of these patients were negroes, 30% were females, 30% were tall and thin, and an age range from seven to seventeen was present.

It is a common misapprehension that this condition must produce symptoms referrable to the hip. Eventual pain, spasm and defective motion at the hip are usual, but eighteen referred all their complaints to the knee. When a symptomatic knee is clinically negative, the hip must next be examined.

Roentgen evidence of epiphyseal abnormality usually is present well in advance of the symptoms which it produces. These become progressively more pronounced as the epiphyseal involvement and loosening or displacement of the femoral head increases in severity. The problem is not so much one of roentgen diagnosis as of comprehension that a roentgenogram of the hip should be made.

ON THE RELATIONSHIP BETWEEN MORBID ANATOMY, TREATMENT AND PROGNOSIS

Consideration of slipped upper femoral epiphyses as a single entity would be fallacious and misleading. Our experience dictates that the condition must be divided into categories before any discussion of treatment and prognosis is valid.

The Stage of Pre-Slip and Minimal Slip

This category includes two groups. In one the epiphysis is diseased but the femoral head is neither separated nor displaced from the femoral neck. In the other the femoral head is displaced but remains in an acceptable position.

Acceptability is, of course, a matter of individual roentgen interpretation. It is recognized that the measurement of the degree of migration does not lend itself easily to rigid mathematic rules because of the illusions created by the x-ray projection or plane, the molding of the neck by the migrating head, and the formation of new bone at the exposed neck end. In general, displacements less than one centimeter and angular deformities less than twenty-five degrees have not been subjected to the substantial risks of avascular necrosis which attend corrective procedures.

Sixty-four hips in these categories were stabilized by Smith-Petersen nails. All of these children were ambulated on crutches. The majority were admonished against weight bearing for periods averaging six months. How faithfully the child obeys such orders over a prolonged period is open to conjecture. Despite this imponderable, the results were uniformly excellent and unmarred by any instance of avascular necrosis.

Whether or not or how much these hips will be troubled by arthritis in years to come is indeterminate, but it is clear that this danger has been minimized by holding the caput femoris in an acceptable position until the risk of further displacement was past.

The Stage of Chronic Unacceptable Slip—"Moderate Slip"

Twenty-six hips showed gross distortion of some duration. That they were long standing lesions was attested by a triangle of new bone formation joining the overhanging caput femoris and the posterior and inferior surface of the femoral neck. It was considered that this mass of callus would resist all but the most forceful of manipulative reductions. All were therefore corrected by cervical osteotomies.

The grossly displaced femoral epiphysis is separated from virtually all capsular blood supply except that contained in the posterior capsular retinaculum. These vessels must be preserved if avascular necrosis is to be avoided. They are immobilized by adjacent callus and fibrous repair when the displacement is of some duration, and apt to be destroyed if this reparative mass is broken up by forceful manipulation or rough operative technique. With this in mind, cervical osteotomy was carried out by removal of a cuneiform wedge generous enough to permit realignment of the fragments without tension or stretching of the posterior neck periosteum.

Nevertheless, five cases (20%) were subsequently complicated by avascular necrosis. Two of these required arthrodesis of the hips. The remaining hips do not show avascular necrosis.

The Stage of Acute Complete Slip

Ten children were treated by reduction and fixation with a Smith-Petersen nail following sudden complete displacement of the femoral head. Six developed avascular necrosis.

These unhappy results provoked a suspicion that forceful early reduction may sometimes be the final straw which adds enough insult to the already compromised local circulation so that the nutritional doom of the femoral head was sealed at the time of treatment. Two of the hips without avascular necrosis in this series were reduced with a closed capsule and two by open reduction. It was necessary to open the capsule to do a cervical osteotomy in three of the ten cases to obtain an acceptable reduction. It is apparent that the capsule must sometimes be opened to obtain early reduction, and that opening the capsule is not necessarily related to the incidence of avascular necrosis.

A satisfactory solution to this vexing problem is not yet at hand. Perhaps it will be found somewhere between the two extremes of early reduction and the premeditated acceptance of malunion and later reconstruction advocated by Heyman.

SUMMARY

Slipped upper femoral epiphysis may be encountered in a young adolescent of any color, sex, or build. The lesion is brought to the attention of the surgeon by symptoms which are occasionally initiated or aggravated by a minor injury and which are not always at the hip but sometimes restricted to the knee. Social, economic, and educational, as well as medical indications, justify its internal fixation.

Subsequent crutch walking increases the load on the other hip which sooner or later became similarly affected in 30% of the children studied. The good hip must be watched closely until its epiphysis closes.

If slipped upper femoral epiphysis had been studied as a single entity, the incidence of avascular necrosis in this series would have been a fallacious 11%. In sixty-four cases not requiring correction, it was zero. In twenty-six cases of later correction by cervical osteotomy, it was 20%, and in ten cases of early reduction and fixation of acute complete displacement, it was 60%.

The lesson is that the lesion should be recognized and the femoral head fixed in good position before it has displaced enough to require reduction.

DISCUSSION

DR. WENDELL A. GROSJEAN (Winfield, Kansas): In opening this discussion I should like to confine my remarks to the paper presented by Dr. Garcia, if I may.

First of all, I must agree that replacement prosthesis is certainly a procedure of considerable magnitude in these older people, with their many infirmities, and it certainly shouldn't be undertaken too lightly. In their comparative series of cases, I am much impressed with the large number of medical problems that they had in the group in which prostheses were used, and it is a little difficult for me to evaluate, really, the mortality between the two on that account.

Of the prostheses that we have used, 54 have been used in fresh displaced intracapsular fractures. We have used the Fred Thompson medullary type prosthesis and the anterior approach in each instance. The age range has been from 49 to 92, the 49-year-old being a feeble-minded individual. Of significance is that 26 of these, almost half, have been in patients 80 years or older.

There were 7 deaths out of the 57, which is about 13 per cent, and these were all in the fresh fracture group. Aside from a 67-year-old female who died on her 34th post-operative day of pulmonary carcinoma, all deaths occurred in patients from 82 to 88 years of age. Since there were 26 in the 80-year group, the mortality for this particular group is then 23 per cent. These deaths occurred in from one to 48 days and included two pneumonia, one aspiration, one cerebral accident, one pulmonary embolus, and one uremia.

One bright note is that there have been only three deaths in the last 44, and the previously mentioned patient dying of pulmonary carcinoma is included in these. The average hospital stay for all of our hip fractures, whether they were intertrochanteric treated by open operation, blind nailing—we have not done any open operations with our nailing—as well as the prosthesis, is approximately the same in those that are uncomplicated, and I repeat "uncomplicated." That's about twelve days. However, this latter group, when they leave the hospital, leave walking reasonably well, which I think is a consideration of some importance.

It seems very obvious that these patients need to be carefully evaluated and that one should consider a procedure such as has been suggested, perhaps blind nailing in some of these poorer-risk old patients in whom pain is the primary consideration.

DR. GEORGE J. CURRY (Flint, Michigan): A few comments on the paper, "Slipped Upper Femoral Epiphysis." I think the premise is good, the discussion is sound, and the conclusions are balanced and rational. Any discussion of this particular subject should emphasize the early recognition and doing something about it *now*. If this is done we can eliminate many adult cripples.

With respect to the paper by Dr. Garcia and his associates, most of us in this audience, I am sure, were waiting for just such a comparison of 100 of one kind and 103 of the other. My compliments are extended to you, Dr. Garcia, for doing this so well. We have done articular replacements on a selected basis, avoiding those with pronounced osteoporosis. A weak acetabulum does not tolerate metal well. The same holds true, of course, for nail fixation.

It is most interesting to hear, and well to emphasize, that both procedures are of a major character. We like the posterior approach for the insertior of a prosthesis. We think it is easier.

Open versus blind nailing is debatable, and I think it's a local habit. It depends upon where you live and what are your experiences. We have done it a few times, but most by blind nailing. The first hip was operated upon twenty years ago. Fifteen hundred have been done since that time with an approximately equal division of intracapsular and intertrochanteric types. I think the blind nailing is a little easier and less time consuming.

DR. JESSE W. MAHONEY (New York, New York): I am aware of the danger of appearing ubiquitous, but I asked Dr. Stack to allow me to have the privilege of making a few comments on Dr. Garcia's paper in light of the experience that we have had at Bellevue. Dr. Garcia asked me to review 100 cases of displaced subcapital and intracapsular fractures on our service treated by blind nailing, which is our method of choice. We did not have time to find out about a hundred, but we did find out about 50, five of which were treated after the method advocated by Dr. Giannestras, of this organization, and we had an 18.4 per cent mortality.

In these 50 cases there were 85 per cent failures, either mechanical or vascular. This may startle Dr. Curry, but it was true of these figures.

(Slide) This is a group of primary replacements in this type of injury, the displaced intracapsular or subcapital fracture, since 1948, these figures being brought together as of December past, 134 cases, and you can see the derivation.

(Slide) Our mortality in the service cases, which in a large city hospital present a marked problem, is 16 per cent. Our mortality in our private cases is 8 per cent. We feel strongly that this is a procedure that is a good one, certainly when properly applied and with proper selection of patients.

DR. ALEXANDER GARCIA, JR. (New York, New York); I would like to thank all the discussers for their comments, and would like to mention that it is very difficult to get two comparable groups of patients if some judgment is exercised in selecting the patients for surgery. In any retrospective study patients fall into groups depending upon the policies of the service, and this is reflected in this study.

Dr. Grosjean mentioned an average hospital stay of 12 days, but these were only the uncomplicated cases. Our hospital stay was determined on the basis of every patient regardless of complications, and obviously there were some that were there for months.

We have no time to discuss open versus closed intracapsular fractures of the hip.

As regards the posterior approach, we favor this at this time, rather than the anterior approach, in the fresh fracture of the hip. If a prosthesis is done as a secondary procedure, many times we choose the anterior approach, especially if there is a flexion contracture.

The operative time is long. I think this is weighted by the fact that many of these cases are the first open reduction done by a resident, and I think this alters it considerably.

I think Dr. Mahoney's statistics merely bear out the point that we would like to make, that the question of whether or not to use a prosthesis is something that requires the judgment of a mature surgeon, and I think the fact that his private cases show a much better mortality statistic here reflects Dr. Mahoney's excellent judgment.

MICROFILTER SHEATHS IN PERIPHERAL NERVE SURGERY:

A Laboratory Report and Preliminary Clinical Study[1]

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Research of the last five decades throws light on biological mechanisms responsible for return of function after precise epineural suture of a severed peripheral nerve. These will be reviewed in order to present a rationale for recent studies aimed at improving methods for peripheral nerve repair. In particular the studies of Huber (8) and Weiss have been invaluable in planning the present investigation. The latter (26) concluded that axoplasm is elaborated in the cell body after observing that the axis cylinder became diminished in caliber distal to a point of constriction and tortuously distended proximal to this level. More recently Pomerat (17) demonstrated that certain cells in the nervous system possess "a rhythmic pulsatile activity" which might be responsible for centrifugal convection of axoplasm. He observed this phenomenon by means of time lapse photorecording of glial cells growing in tissue culture. These hydrodynamic observations seem to offer a reasonable explanation for regrowth of a severed axon. The studies of Ramon y Cajal (18), Dustin (6), Loeb (11), Harrison (7), and Weiss (22), showed that regenerating cells may be oriented by the inter-

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faces they encounter and the latter referred to this as "contact guidance." Thus, the axons which cross into the distal stump of a severed peripheral nerve eventually reach motor and sensory terminals by virtue of "contact guidance" along the remaining longitudinally oriented sheaths of Schwann. The mechanisms by which axons establish continuity with the terminals remains to be elucidated.

In peripheral nerve repair, it is generally conceded that precise approximation of epineurium to epineurium, with due regard to orientation of the proximal and distal fascicular arrangement, is essential to success. In this way, extraneural invasion of the site of repair is minimized and proper channels are made available to regenerating axons. However, after the most meticulous repair, functional return rarely approaches that existing prior to transection (29). In part, this may be accounted for on the basis of ingrowth of extraneural connective tissue. Thus, interfaces with random orientation become available for "contact guidance" of regenerating intraneural tissues. Initial distortion of the supporting matrix of the nerve may block the progress of regenerating axons or deflect them from a longitudinal course so that they escape from the confines of the epineurium or enter inappropriate channels. Later, shrinkage of a cicatrix leads to constriction of axons with attendant loss of function. For these reasons, shielding of the suture line has been attempted with various substances: synthetics, tantalum, gold, autogenous and preserved homogenous grafts including blood vessels. Weiss (23, 25), who devised the "sleeve splicing" method for peripheral nerve repair within arterial or annealed tantalum cuffs, evaluates the attempts of others, between the years 1880 and 1943, to shield suture lines with various materials. In spite of this prodigious effort, no entirely satisfactory substance was found.

Algire (1) used Millipore filter chambers in studying the homograft response. The biophysical properties of this plastic, demonstrated in his research, seemed to satisfy many of the requirements thought necessary for success with a tubulation technique for peripheral nerve repair. As pointed out elsewhere (2) Millipore is a cellulose acetate, monomolecular filter which is relatively inert in tissues. If the plastic is clean, the tissue response is free of foreign body giant cells. It has a high flow rate, since 80% of its volume is composed of pores (maximum diameter 0.45μ in the H.A. formulation), arranged approximately perpendicular to the surface. These physical characteristics are of value during the early phases of regeneration when Millipore is used to encase a site of neural regeneration. The outer surface of the filter barricades the line of repair against invasion by extraneural cells; while the inner surface presents an adequate interface for "contact guidance" of regenerating connective tissue cells crossing the gap until continuity in the outer covering of the nerve is re-established. Diffusion of extracellular fluids through the membrane satisfies the nutritional requirements in the early stages of the regenerative process, before the blood supply is re-established.

In the past 5 years, this plastic has been used in developing a tubulation technique for repair of transected peripheral nerves in laboratory animals (2, 4, 5, 9, 14). The favorable results obtained with the method in the laboratory justified limited use on a clinical level. However, two problems prevented success when dealing with irreducible gaps of appreciable length in the major nerves of man. The first of these was caused by the failure of Millipore to withstand strain. This unsubstantial material collapsed with compression and its surface was easily ruptured, when used to span long gaps with diameters in excess of 3 mm. Various mechanical techniques used in tube fabrication failed to solve this problem. The second difficulty centered about the architecture of the fibrin strands within the gap. Since cells and axons migrate by "contact guidance," it is important that these strands be arranged in a pattern which will lead to longitudinal growth. As the length and diameter of the gap increases, it becomes more difficult to obtain the desired orientation of the substrate. The present investigation was aimed at attacking both problems. Therefore, internal bolstering of Millipore was attempted with various scaffolding materials which could be absorbed during neural regeneration. Initial trials with reconstituted collagen rods and keratin strips[3] were unsuccessful. Despite the generally unfavorable reports (12, 20, 28) concerning the use of peripheral nerve homografts in man, it was decided to evaluate this material as an internal support for Millipore.

METHODS

Tubulation repair of the posterior tibial division of the sciatic nerve of the cat was carried out by methods described below and illustrated in (Fig. 1). Each operation had in common dissection of a 4 cm length of the posterior tibial division from the peroneal component. Specially prepared, silicone-coated, undyed No. 6-0 silk[4] was used in neural tissue, whereas commercially available, black silk was used throughout the remainder of the operations.

End to end suture, (Fig. 1A): After complete transection of the posterior tibial nerve, the severed stumps were approximated with one or two transneural sutures. On one side, the site of repair was shielded within a cylinder of reinforced Millipore (5). Each animal served as its own control by repeating the same procedure on the opposite side but omitting the Millipore sheath.

Repair of unreduced gaps without peripheral nerve grafts, (Fig. 1B): Gaps, 1–2.5 cm in length, were created by nerve resection. Both ends of a sling stitch placed in the proximal stump were pulled through a Millipore tube of appropriate length. Next, one end of the sling stitch was passed through the distal stump and tied to the other without tension. Then, the tube was pulled down to a point where the gap and at least 5–10 mm of the opposing stumps were covered.

Repair of unreduced gaps with nerve grafts, (Fig. 1C): 1 cm gaps were spanned with grafts of equivalent length, held in contact with the proximal and distal stumps by one or two epineural sutures. The nerve caliber varied from 2.5–

[3] This material was made available through the generosity of Dr. A. N. Silvetti, Department of Plastic Surgery, University of Texas, Medical Branch, Galveston, Texas.

[4] This process developed especially for this project by Dr. R. R. McGregor, Associate Director of the Dow Corning Corporation, Midland, Michigan, was later modified for production in the laboratory of the Surgical Products Division of the American Cyanamid Company. The authors express gratitude to both corporations for having made this suture material available.

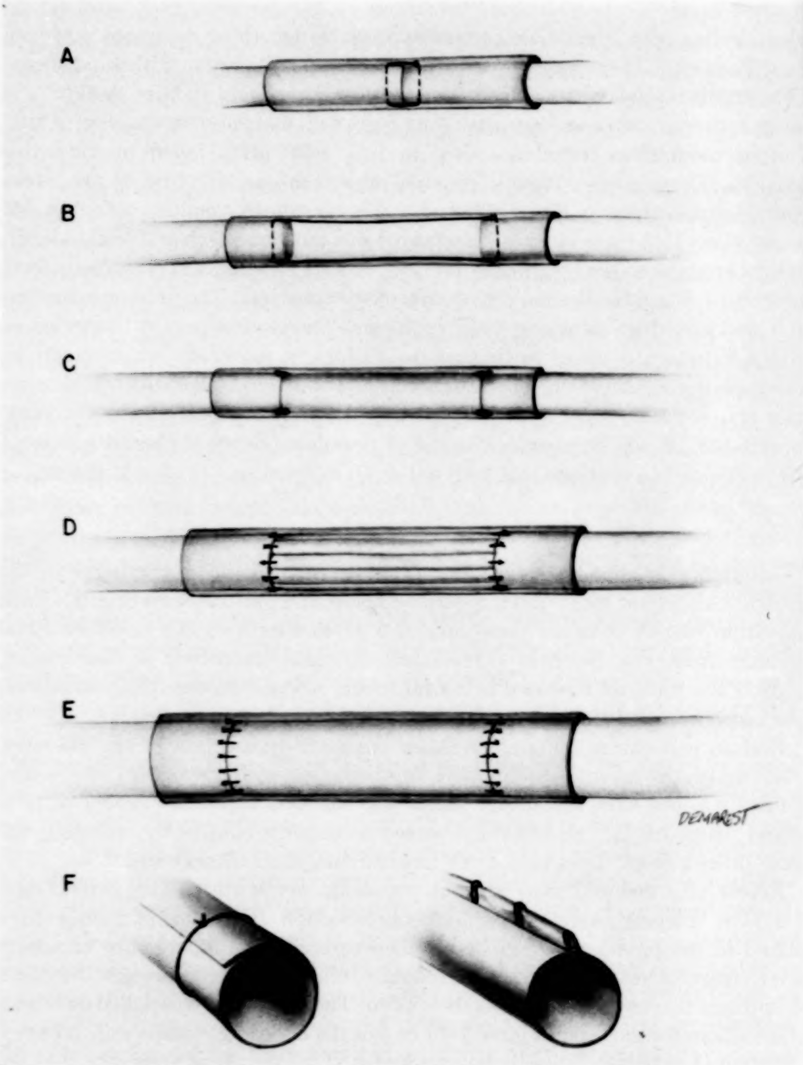

FIG. 1. Diagrammatic illustrations of the methods employed.

3 mm. To avoid displacement of grafts, tubes were fashioned from sheets of Millipore by rolling the edges together into a cuff, which in turn was secured by silver clips or by overlapping the edges and fixing them beneath silicone covered silk sutures, (Fig. 1F). The following types of grafts were used: autografts, frozen homografts, freeze-dried homografts, and frozen-irradiated homografts. Autografting consisted of transferring a 1 cm segment of posterior tibial division of the sciatic nerve to a gap of equivalent length in the corresponding nerve on the

opposite leg. The donor site was filled with a segment of frozen homograft. Freeze-dried, and frozen-irradiated homografts were similarly handled in unilateral operations. All grafts except the frozen-irradiated type were procured under aseptic conditions. The freeze-dried grafts were placed on the walls of sterile test tubes which were corked and then immersed in CO_2 absolute alcohol slush at −76° C for 15 minutes. Next, the tubes containing the frozen nerve segments were uncorked and transferred to a laboratory freeze-drying apparatus. The drying chamber was precooled to −76° C, the condenser to −196° C with liquid N_2 and a vacuum (less than 0.1 mm Hg) was maintained in the apparatus by a Cenco "Megavac" pump, in series with an oil diffusion pump. The drying cycle lasted for 48 hours with gradual warming of the tissues to room temperature during the last 24 hours. Residual moisture determinations were not made. The dried grafts were stored under vacuum, at room temperature, in sealed test tubes until use, when they were reconstituted with saline. Frozen grafts were stored in sterile test tubes at −76° C. Frozen-irradiated nerves were packaged in three, heat-sealed, mylarpolyethylene envelopes, stored at −76° C, and shipped in dry ice for sterilization by 2,000,000 rep, delivered by a 3 mev van de Graaff accelerator. Storage continued at −76° C, until used.

To simulate conditions encountered in grafting the major nerves of man, aseptically procured, freeze-dried, small caliber, cable grafts[5] were placed in the posterior tibial division of the sciatic nerves of large dogs and goats,[6] (Fig. 1D). In the case of the former, the gaps measured 2.5–3 cm in length and 4 mm in diameter. In the latter, gaps were 3–3.5 cm in length and 7 mm in diameter. The stumps were stabilized by 2 epineural sling stitches before the grafts were laid in. Wherever possible, the grafts were fixed to the proximal and distal stumps by epineural sutures. Full-thickness, freeze-dried, 3.5 cm grafts were used to span gaps of similar length in other goats (Fig. 1E). The Millipore tubes were fashioned by either of the two methods described above, (Fig. 1F).

RESULTS

The data reported below summarize the results of experiments carried out on 200 cats, 9 dogs, and 9 goats.

End-to-end suture: Serial observations between the 4th and 45th day show that the pattern of regeneration in Millipore-shielded specimens is more orderly than that seen in unshielded controls. Beneath the microfilter, regenerating tissues are aligned parallel to the long axis of the tube. This is in strong contrast to the random pattern existing at the margins of the unshielded specimens, where extraneural tissue invades intraneural areas and deflects axons from a longitudinal passage across the gap. The contrast is demonstrated in (Fig. 2, 3).

[5] Gratitude is expressed to Captain G. W. Hyatt, M.C., U.S.N., and his associates in the Tissue Bank of the Naval Medical School, Bethesda, Maryland, for processing the homografts used in this phase of the project.

[6] Gratitude is expressed to Drs. W. F. Windle, Chief, Laboratory of Neuroanatomical Sciences, and Dr. W. I. Gay, Chief, Animal Hospital Section, Laboratory Aids Branch, and his associate Dr. S. J. Urich, National Institutes of Health, Bethesda, Maryland, for making these facilities available and for assistance in this phase of the project.

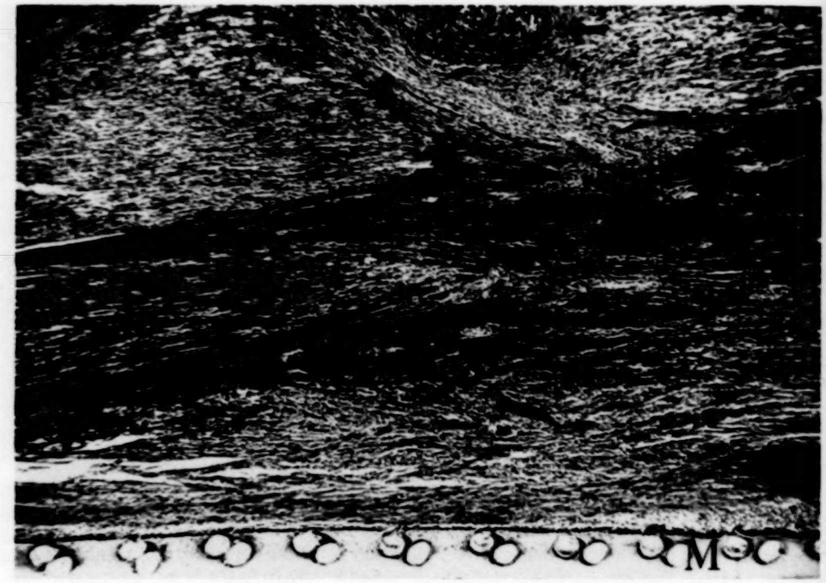

FIG. 2. Specimens from a feline posterior tibial nerve 45 days after transection, end-to-end transneural suture, and Millipore tubulation. Arrow indicates the site of a suture. Note deflection of longitudinal pattern of regeneration in this area and the minor cellular reaction caused by the suture. "M" marks reinforced Millipore sheath. Masson, approximately ×40

FIG. 3. Specimen from the opposite posterior tibial nerve in the same cat in which an identical operation was performed but the Millipore sheath omitted. Masson, approximately ×40

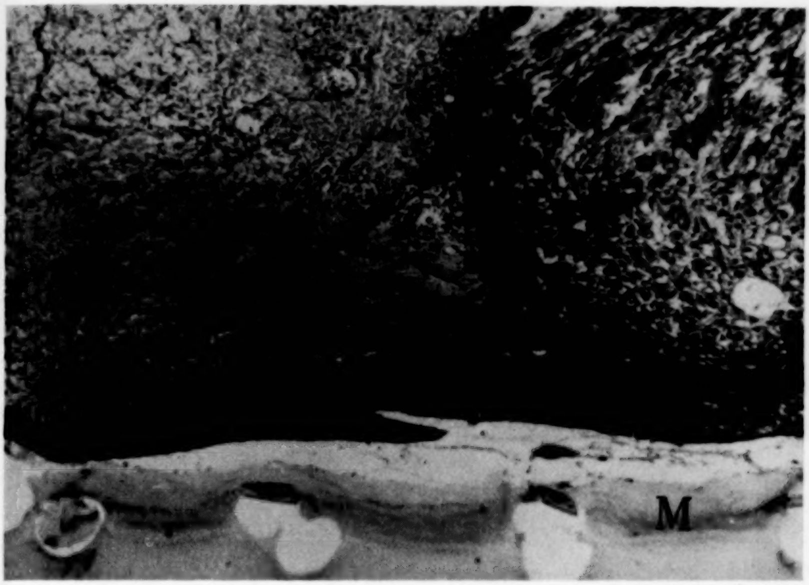

FIG. 4. A four day feline specimen showing the fibrin strands in the plasma clot arching from the nerve stump "N" toward the inner surface of the Millipore "M." PTAH, approximately ×90

Repair of unreduced gaps without nerve grafts: Spindle-shaped cells invade the gap first, progress along the inner surface of the Millipore tube, following the arching fibrin strands which develop in a clotted mixture of plasma and occasional blood cells which accumulate between the stumps, (Fig. 4). These cells, migrating from the opposing stumps, join by the middle of the third week to form a connective tissue continuum, well in advance of the blood supply, (Fig. 5). Endoneural regeneration and Schwann cell proliferation run parallel with regenerating capillaries which grow out from both stumps to re-establish continuity of the vascular bed. Axons, the last structures to cross the gap, do this in association with cords of Schwann cells and enter the distal stump by the 30th day.

In both the end-to-end suture and long gap experiments, return of function exceeds 90% judged by strain gauge testing of muscular contraction on the operated side and compared with that on the unoperated, control side. Likewise, comparative weights of the calf musculature are almost identical. The percentage of return of function is also high in both types of experiments when Millipore is not used, but the anatomical quality of regeneration is poorer due to a certain degree of neuroma formation (10). In addition, it has been shown that gamma efferent fibers do not regenerate as rapidly in the "long gap" type of preparations which are not tubulated. A direct relationship has been demonstrated between re-establishment of the gamma efferent innervation and competent use of the calf musculature (21).

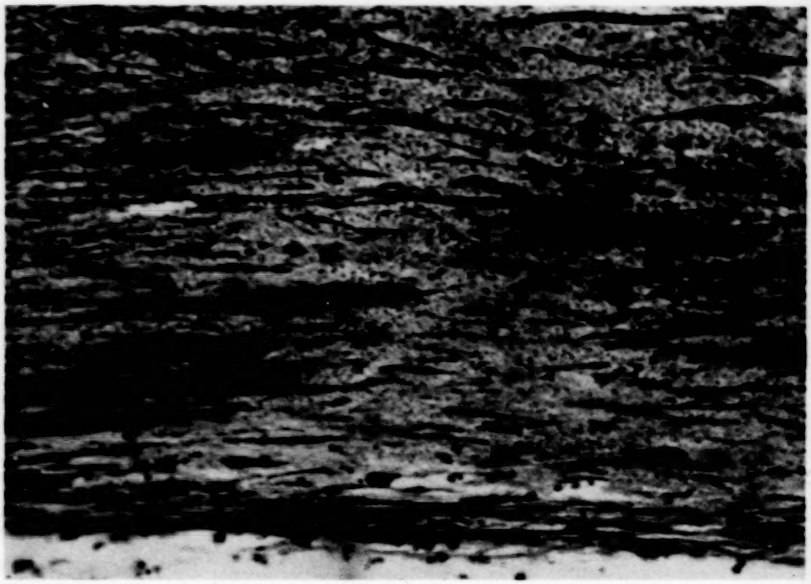

FIG. 5. Arrows indicate the directions in which capillaries are regenerating to re-establish continuity of the blood supply, within the already reconstituted epineurium, "E." H&E, approximately ×220

Repair of unreduced gaps with nerve grafts: In the cat, frozen, freeze-dried, frozen-irradiated homografts, and autografts are almost completely revascularized by capillary invasion from both stumps in 30 days. In all types of grafts, the original tissues are partially invaded by other types of host cells at 30 days. Replacement is well advanced by 70 days, although some residual collagen fibers and fragmented axons are present. At 105 days, reorganization is practically complete. Electrical stimulation proximal to the grafted areas evokes a contraction in the gastrocnemius and soleus muscles as early as 70 days. Regenerated, functional axons can be seen at this time. In specimens 14–19 months old, the fascicular pattern of the graft is retained, even though the grafted tissue is completely replaced. This configuration is not seen when unreduced gaps are not filled with grafts. The fascicular pattern of the graft rarely coincides with that of the host and there is frequent distortion of the axon pattern at the proximal and distal junctions of the grafted area. In addition, transneural sutures uniting the host and graft disrupt the axon pattern. Nevertheless, the muscle strength and weight exceeds 90% of normal, 14–19 months after grafting.

The grafted dog nerves were examined 9 months after operation. Return of function was observed by clinical observation and verified by electrical stimulation. The histological picture is uniform in all specimens. At the proximal and distal junctions of the grafts with the host nerve, the axon pattern is distorted

(Fig. 6). This disturbance is greatest at the proximal junction, where axons and columns of Schwann cells tend to pile up, as though thwarted in their distal progress. Consequently, as they twist and turn, the bulk of the proximal stump is increased. Just distal to this area, axons enter the pre-existing channels of the grafts and follow the longitudinal pathways of the fascicular pattern of the donor nerve. As they enter the distal stump, there is distortion of alignment, but it is less marked than at the proximal junction. Distal to this, axons follow the normal longitudinal pattern of the host nerve but their diameters are less than those seen in the proximal stump.

Specimens in goats ranged from 2–7 months in age. Axons regenerate across cable grafts in these animals in a manner similar to that seen in the smaller nerves of dogs. The amount of deflection at the proximal junction of cable grafts and the severed nerves varies directly with the number of grafts used. The deflection is greatest in a goat in which 20 grafts span the gap. Full-thickness grafts show the least distortion at the proximal junction (Fig. 7). This still exceeds the amount seen distally. In younger, full-thickness grafts, axons enter the graft before revascularization is complete in the mid-portion. Wherever axons have penetrated, reconstitution of the graft by host cells is well advanced. Ghosts of remaining donor axons are visible at two months in the mid-portion of the graft, but at 4½ months no ghost axons, pyknotic nuclei, or debris are seen

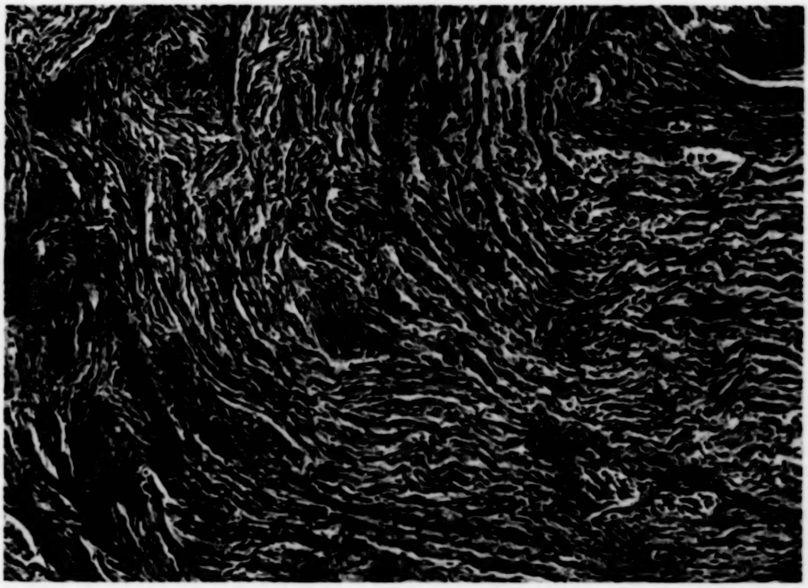

FIG. 6. To show the distorted pattern of axonal regeneration at the proximal junction of the nerve and cable grafts in a dog. Arrows indicate the direction of the migration. Bodian, approximately ×90

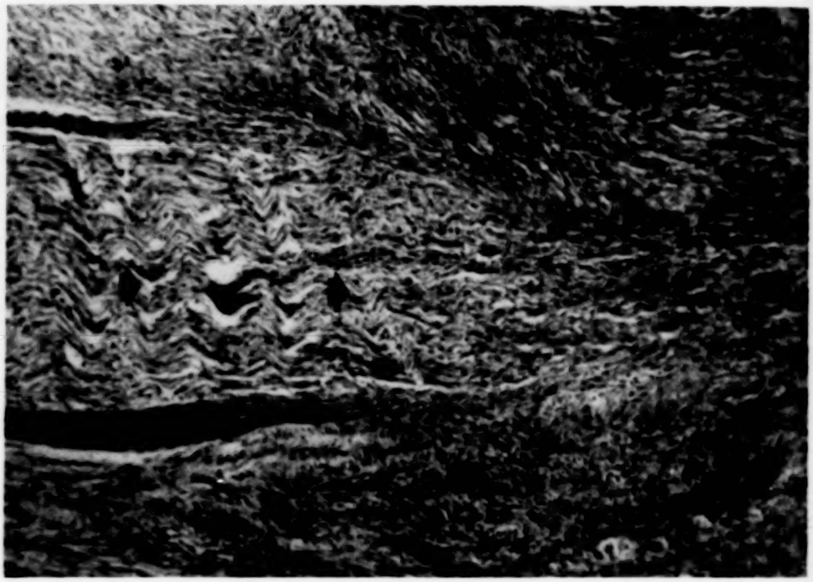

FIG. 7. Proximal junction of a full-thickness graft and nerve in a goat. Arrows indicate the direction of migration of axons which are leaving a host fascicle and entering the graft just beyond the tip of the innermost arrow. Bodian, approximately ×90

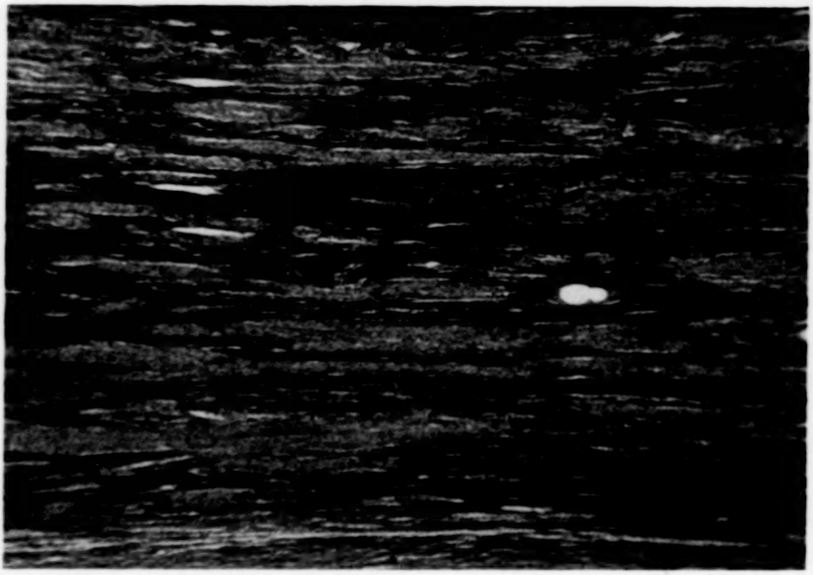

FIG. 8. The pattern of regeneration at the mid-point in a cable graft in a goat. Bodian, approximately ×40

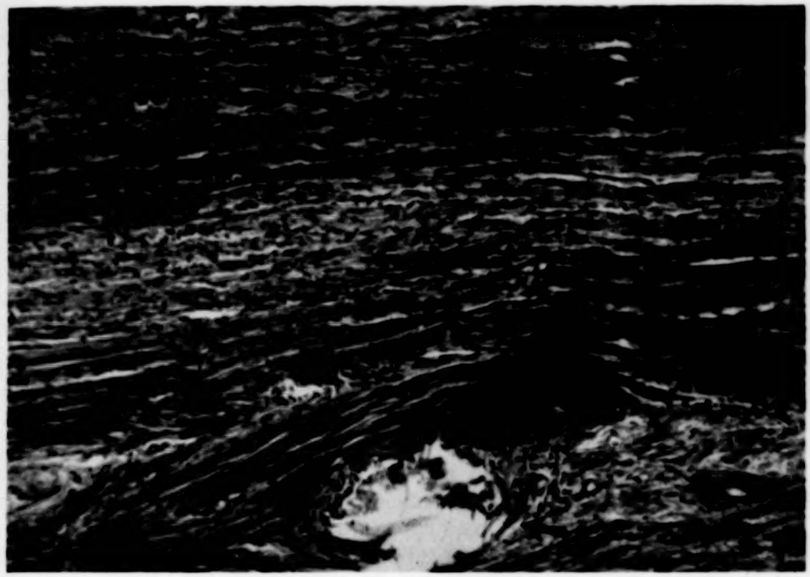

FIG. 9. The arrow indicates the site of an epineural suture that has penetrated a nerve fascicle. Note the minimal degree of cellular reaction evoked and distortion of the pattern of regeneration. Bodian, approximately ×90

and cellular activity within the graft resembling Wallerian degeneration has subsided. At this time, revascularization is complete and axons have entered the distal stump. The amount of collagen found in full-thickness grafts is less than within cable grafts. Hyalinized collagen bundles, in the epineurium of cable grafts, are invaded by host fibroblasts and reconstituted. More collagen is noted in the distal portion of both types of grafts. This, however, does not distort the passage of axons along the reconstituted Schwann tubules in the grafts, (Fig. 8). In both types of grafts, the epineurium is longitudinally oriented. Silicone-coated silk sutures passed through this structure cause minimal distortion and cellular reaction, (Fig. 9). There does not appear to be an appreciable amount of axon migration along the epineural surfaces of cable grafts. No evidence of a homograft reaction, as characterized by perivascular infiltration of round cells, plasma cells, and lymphoctyes was observed in the goat specimens or in the dog and cat specimens. At 5 months, active, plantar flexion returned and after 7 months bioelectric evidence of return of function was obtained.

Clinical Experience

In January 1957, Millipore was employed as a shield for a line of epineural sutures used in maintaining apposition between the ends of severed peripheral nerves in man. This step was justified on the basis of laboratory findings de-

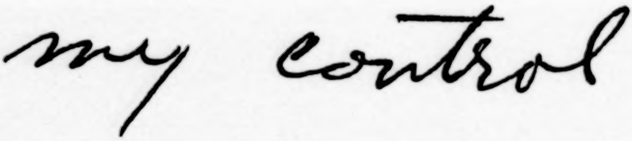

FIG. 10. Specimen of the handwriting of a man 29 months after the repair of median and ulnar nerves.

scribed above. Since there is uncertainty about the extent of damage in freshly traumatized nerves, this method was applied only in individuals with long-standing injuries. In addition, this course reduced the chance of sepsis arising in conjunction with the implantation of a foreign body in a freshly contaminated wound.

Three individuals in this group are of particular interest. The first is a right-handed man, who, after secondary suture of the median and ulnar nerves on this side, now has an excellent handwriting (Fig. 10) and a useful right hand with which he earns a living as a bartender. In the case of the ulnar nerve, it was necessary to repair it in two divisions. This operation was carried out 6 months after attempted neurorrhaphy, performed elsewhere, had led to neuroma formation. The second is a woman who has effective return of strength and coordination in the muscles innervated by her right median nerve. Twenty-nine months prior to operation, this nerve had been accidentally severed 5 cm proximal to the medial epicondyle and not repaired. The operative procedure consisted of neuroma resection and approximation of the opposing stumps with epineural sutures. Twenty-four months later, Dr. Joseph Moldaver's[7] testing of the muscles innervated by the repaired nerve showed chronaxie figures "close to the normal with diminution of the amplitude of the contraction." Possibly the most interesting observation is that of continuous return of function over a two year period in the muscles innervated by a radial nerve in a woman now 79 years of age. She had lost 10 cm of this nerve in an over-riding fracture of her humerus three months prior to repair. Precise epineural suture was impossible because of a 5 to 1 discrepancy between the diameters of the proximal and distal stumps. Full apposition was not attempted, but approximation of the severed ends was maintained by means of four epineural sutures which spanned a 2 mm gap remaining between the stumps. This line of repair was shielded with a Millipore cone rather than a tube in order to accommodate the discrepancy existing between the diameters of the stumps.

DISCUSSION

In the cat, the regenerative potential of the peripheral nervous system is strong. Axons will bridge a 4–5 cm gap in the posterior tibial nerve, when that

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[7] Gratitude is expressed to Dr. J. Moldaver, Department of Neurology, College of Physicians and Surgeons, for the continued chronaxie studies that have been made in the clinical phase of the project.

length of nerve is resected with minimal trauma to the surrounding tissues. The peroneal component of the sciatic nerve and the hamstring muscles offer "contact guidance" to the regenerating cells and axons in their migration toward the distal stump. The anatomical pattern of regeneration along these unshielded interfaces is not orderly, but axons traverse the randomly oriented cicatrix and enter the channels of the distal segment of the nerve in sufficient numbers to restore a remarkably high percentage of function in the calf muscles. Why is this phenomenon, observed in the sciatic nerve of the cat, not seen when the major nerves are severed in man? A possible answer is that trauma of sufficient degree to cause a loss of anatomical continuity in a nerve usually disrupts soft tissue planes and leaves in its wake an ideal milieu for production of an extensive, disorganized cicatrix. Debridement further prejudices the situation.

Weiss (23, 25) on the strength of his "in vitro" studies, devised a method for peripheral nerve repair which he later termed "sleeve splicing". In brief, this consisted of shielding the proximal and distal stumps of a severed nerve within a segment of preserved artery or a cuff of annealed tantalum. He emphasized that it was essential to leave clotted, whole blood in the intervening gap. By this means, an excellent anatomical quality of regeneration, with high percentage of return of function, was obtained in his laboratory animals. His research indicated that longitudinal stress, exerted through the stumps of the severed nerve and intervening clot, caused the fibrin strands, during the process of syneresis, to become aligned parallel to the direction of the force. Thus, a properly oriented "contact guidance" system was achieved. Sutures were omitted from this technique in order to permit the orienting action of linear tension. Later, he and his associates, Matson and Alexander, (13) modified the method to bridge long deficits in the posterior tibial nerves of monkeys by adding a span of multiple nylon or tantalum filaments drawn through the proximal and distal nerve stumps. It was this last development, which gave impetus to the neural regeneration program which started 5 years ago in these laboratories, when Millipore became available. Early in the project, it was found that the Millipore tubulation technique for repairing long deficits without nerve grafts failed, if the gap was not spanned by a single sling stitch. Further, as might be expected on the basis of Weiss' research, the pattern of the fibrin strands within the clotted mixture of plasma, and blood cells was not longitudinal, but arched as illustrated in (Fig. 4). Nevertheless, the quality of regeneration was excellent. What then was the basis for success with the newer technique? As stated elsewhere (2) it was believed that fixation of the nerve stumps within the Millipore tube by a sling stitch increased the surface stability of this relatively flexible structure. Thus, the chance of premature clot syneresis was reduced and the essential fibrin scaffold preserved for "contact guidance" of the earliest regenerating cells. The arching, fibrin strands, (Fig. 4) at the extremes of the gap provide an adequate substrate for guidance of spindle cells toward the internal surface of the Millipore tube. Once there, these cells migrate more rapidly than those located more centrally. This is evinced, additionally, by the fact that the epineurium is the first component of a severed nerve to be reconstituted within Millipore. It is presumed that the nutritional advantage offered by interstitial fluids diffusing through the pores permits a more rapid growth rate. On the other hand, the cells more removed from the surface are less well nourished because of temporary impairment of the blood supply, and, as a consequence, grow more slowly. If this thesis is correct, it accounts not only for the initial longitudinal orientation of the epineurium but also for the subsequent longitudinal alignment of other components of the nerve (Fig. 5), as they regenerate in their respective order. Implanting a graft in the gap seems to provide more longitudinally oriented interfaces for aligning regenerating neural tissues than can be obtained by fibrin strands. As time passes and the blood supply recovers from thrombosis which follows the trauma of transection, angioblasts receive "contact guidance" from the reconstituted epineurium, with the result that a linear blood supply is restored. The rate of regeneration of the blood supply appears to influence the rate of regeneration of the other components of the nerve, with the exception of the axons. These structures are membranous extensions of neurons, located proximal to the area of injury. Therefore, their rate of migration is not totally dependent upon the nutrition available in the regenerating tissues at the transection site. As reported elsewhere (2) axons can grow into a clot, while the general regenerative process is retarded by the use of nonporous Millipore. Under these circumstances, they extended beyond points reached by the cells which later were destined to form the epineurium.

The report of our limited clinical experience is not to be construed as an unqualified recommendation for the addition of a Millipore shield to the site of repair of a peripheral nerve. Millipore is fragile and it almost invariably breaks with time. Further, as has been shown elsewhere, calcium becomes deposited within the substance of Millipore (3). Possibly this adds to its fragility. Each break in the surface of the plastic is followed by proliferation of a pseudomembrane about the fragments or exposed reinforcing matrix. However, in experimental animals the encasing membrane and contained Millipore sheath remains under 1 mm in thickness and by gross examination, there does not appear to be any constriction at either end of the cuff. To date, no deleterious effect can be attributed to Millipore that has remained in chronic animal preparations or human beings. Removal of Millipore, once longitudinal orientation and regeneration of the epineurium is complete, does not interfere with further neural regeneration in animals. All patients in the pilot program are being examined periodically by clinical and bioelectric means, to detect a delayed reaction which might necessitate removal of the plastic. These points are raised in order that others using Millipore may be aware of its tendency to fracture and calcification "in vivo" and to give assurance that removal, if it becomes indicated, probably will not have an adverse effect on regeneration once the epineurium has been reconstituted.

As soon as the tubulation technique for bridging long gaps in feline sciatic nerves without nerve grafts had been standardized, the method was given limited clinical trial in three healthy young males with irreducible gaps in major peripheral nerves. These were common peroneal, ulnar, and 5th and 6th cervical nerves distal to the points of exit from their respective neural foramina and proximal to the formation of the lateral cord of the brachial plexus. Repair attempted by this means failed in all three individuals. Re-exploration of the thigh, in which the peroneal nerve deficit existed, showed that in spite of adding helices of nylon to the standard reinforcing matrix of the tube, the cylinder had been crushed to a ribbon. Evidently, the effort at reinforcement was inadequate in resisting lateral compression exerted by the surrounding muscles. The other two operative sites were not re-explored, but it was presumed that the walls of these tubes met with the same fate, since no evidence of return of function was obtained with adequate passage of time.

To strengthen the tubes, reinforcement of Millipore with stainless steel mesh was tried, but discarded because it led to excessive external scarring. Therefore, the simple tubulation method for peripheral nerve repair was discarded and internal bolstering of Millipore was attempted first with collagen rods and later with reconstituted keratin strips. When these proved to be unsatisfactory, peripheral nerve grafts were employed for internal reinforcement. The data presented above show that Millipore may be successfully bolstered with various types of nerve grafts and that these grafts serve as a scaffold for migrating axons which eventually restore function. However, what is more significant is that autogenous, fresh frozen, freeze-dried, or frozen-irradiated homografts produce an identical pattern of regeneration. This has caused recent emphasis to be placed on the use of frozen-irradiated tissue, since it simplifies nerve banking by eliminating aseptic procurement. Prior to obtaining data from the use of frozen-irradiated homografts in cats, the experiments in large dogs and goats reported above were in progress with aseptically procured freeze-dried homografts. The latter study was aimed at evaluating Millipore as a shield for gaps filled with preserved homografts in nerves with diameters equal to the major nerves of man.

These experiments indicate that cable or full-thickness freeze-dried homografts effectively support the Millipore sheath which protects them while providing an absorbable scaffold for regenerating axons. In addition, the present investigation shows that full-thickness grafts offer greater advantages than cable grafts. In both types "creeping substitution" by host cells replaces the nonvital endoneurium and Schwann tubules of the grafts. Regenerating axons migrate along these reconstituted pathways and restoration of function ensues. In full-thickness grafts, the longitudinal alignment of the regenerated epineurium prevents escape of axons to the surface. The fascicular arrangement within a graft rarely, if ever, corresponds with that of the proximal and distal stump of a severed nerve. This may be a factor contributing to distortion of axons as they cross these junctions. Distortion is even greater when cable grafts are employed, since there are fewer Schwann tubules for the passage of regenerating axons. The deficit is not compensated for by axon migration along the surface of the individual grafts, because epineurium does not seem to provide an optimal scaffold. This accounts for the "traffic congestion" seen at the junction of cable grafts and the proximal segment of the nerve, where impeded axons deprived of access to channels for migration twist and turn as in a neuroma. Despite this, sufficient numbers cross the grafts, reach the distal stump and eventually restore function. Millipore barricades the junctions of the graft and host against fibroblastic invasion and prevents constriction of the graft by extraneural adhesions.

Weiss (24, 27) developed the "frozen-dried" peripheral nerve homograft technique for bridging defects in the sciatic nerves of rats, cats, and monkeys. The data derived from the present studies amplify the work of Weiss by showing that preserved homografts provide a scaffold for neural regeneration across gaps in peripheral nerves of animals with calibers equal to those of man. In addition, the results suggest that substitution of microporous filter shields for impervious tantalum might give better results than those reported by Lyons and Woodhall (12) after clinical employment of freeze-dried peripheral nerve homografts. Therefore, full-thickness, preserved homografts, shielded with Millipore seem to merit trial in bridging irreducible gaps which are not longer than 3.5 cm, in the major peripheral nerves of man. It remains for research in progress to determine the ultimate linear limits of the technique.

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REFERENCES

1. Algire, G. H., Weaver, J. and Prehn, R. Growth of cells *in vivo* in diffusion chambers. I. Survival of homografts in immunized mice. J. Nat. Cancer Inst., **15:** 493–507, 1954.
2. Bassett, C. A. L., Campbell, J. B., and Husby, J. Peripheral nerve and spinal cord regeneration: factors leading to success of a tubulation technique employing Millipore. Exp. Neurol., **1:** 386–406, 1959.
3. Bassett, C. A. L., and Campbell, J. B. Calcification of Millipore *in vivo*. Transplant. Bull., **26:** 132–133, 1960.
4. Campbell, J. B., Bassett, C. A. L., Girado, J. M., Seymour, R. J., and Rossi, J. P. Application of monomolecular filter tubes in bridging gaps in peripheral nerves and for prevention of neuroma formation: a preliminary report. J. Neurosurg., **13:** 635–637, 1956.
5. Campbell, J. B., and Bassett, C. A. L. The surgical application of monomolecular filters (Millipore) to bridge gaps in peripheral nerves and to prevent neuroma formation. Surg. Forum, **7:** 570–574, 1957.
6. Dustin, A. P. Le rôle des tropismes et de l'odogenese dans la régénération du système nerveux. Arch. Biol., **25:** 269–388, 1910.
7. Harrison, R. G. The cultivation of tissues in extraneous media as a method of morphogenetic study. Anat. Rec., **6:** 181–193, 1912.
8. Huber, G. C. Experimental observations on peripheral nerve repairs. In U.S. Surgeon-

General's Office. *The Medical Department of the United States Army in the World War.* **11:** 1091–1283, Part 1, U.S. Government Printing Office. Washington, 1927.

9. Husby, J. Axon regeneration across gaps in adult feline sciatic nerves using Millipore filter tubulation. Anat. Rec., **130:** 317, 1958.
10. Husby, J. Unpublished data.
11. Loeb, L. Growth of tissues in culture media and its significance for the analysis of growth phenomena. Anat. Rec., **6:** 109–120, 1912.
12. Lyons, W. R., and Woodhall, B. *Atlas of Peripheral Nerve Injuries.* W. B. Saunders, Philadelphia, 1949.
13. Matson, D. A., Alexander, E., and Weiss, P. Experiments on the bridging of gaps in severed peripheral nerves of monkeys. J. Neurosurg., **5:** 230–248, 1948.
14. Noback, C. R., Husby, J., Girado, J. M., Bassett, C. A. L., and Campbell, J. B. Neural regeneration across long gaps in mammalian peripheral nerves: Early morphological findings. Anat. Rec., **131:** 633–647, 1958.
15. Pate, J. W. Transplantation of preserved nonviable tisseus. Naval Medical Research Institute. Lecture and Review Series **53–5:** 61–68, 1953.
16. Phemister, D. B. The fate of transplanted bone and regenerative power of its various constituents. Surg. Gynec. Obst., **19:** 303–333, 1914.
17. Pomerat, C. M. Dynamic cytology in experimental medicine. U. S. Armed Forces M. J., **4:** 11–21, 1953.
18. Ramón y Cajal, S. *Degeneration and Regeneration of the Nervous System.* Trans. by May, R. M., **1:** 1–396, Oxford Univ. Press, London, 1928.
19. Rey, L. R. Personal communication.
20. Seddon, H. J. Nerve grafting and other unusual forms of nerve repair. 389–417. In *Peripheral Nerve Injuries* (Seddon, H. J., Editor) (Medical Research Council Special Report Series, 282). H. M. Stationery Office, London, 1954.
21. Thulin, C.-A. Electrophysiological studies of peripheral nerve regeneration with special reference to small diameter (gamma) fibers. Exp. Neurol., **2:** 598–612, 1960.
22. Weiss, P. Nerve patterns: The mechanics of nerve growth. Growth (suppl.), **5:** 163–203, 1941.
23. Weiss, P. Nerve regeneration in the rat following tubular splicing of severed nerves. Arch. Surg., **46:** 525–547, 1943.
24. Weiss, P. Repair of peripheral nerves by grafts of frozen-dried nerve. Proc. Soc. Exper. Biol. and Med., **53:** 326–328, 1943.
25. Weiss, P. The technology of nerve regeneration: A review. Sutureless tubulation and related methods of repair. J. Neurosurg., **1:** 400–450, 1944.
26. Weiss, P. Damming of axoplasm in constricted nerve: A sign of perpetual growth in nerve fibers. Anat. Rec., **88:** 464–465, 1944.
27. Weiss, P. Functional nerve regeneration through frozen-dried nerve grafts in cats and monkeys. Proc. Soc. Exper. Biol. and Med., **54:** 277–279, 1945.
28. Woodhall, B. and Beebe, G. W., Editors. *Peripheral Nerve Regeneration. A Follow-up of 3,656 World War II Injuries.* U. S. Government Printing Office, Wash., 1957.
29. Zachary, R. B. Results of nerve suture. 254–388. In *Peripheral Nerve Injuries* (Seddon, H. J., Editor) (Medical Research Council Special Report Series, 282). H. M. Stationery Office, London, 1954.

DISCUSSION

Dr. Ralph G. Carothers (Cincinnati, Ohio): Dr. Mayfield is discussing Dr. Campbell's paper only. He says he does not wish to be facetious, but he finds himself again in an analogous position to that of the "old billiard drinker," where the essayists have presented most convincing data, the experiments were carefully planned, the controls critically studied and the data lucidly presented. Moreover, it applies to a clinical area where past experience leaves much to be desired.

If one were to judge this presentation without previous personal experience, it would be reasonable to assume that the answer to peripheral nerve repair and regrowth had been gained; but, having been trained by a peripheral nerve surgeon of World War I and having served as a peripheral nerve surgeon in World War II, I personally am aware of the futility of wrappers and grafts heretofore and also of the tremendous difference between animal and man in potency of nerve regenerated.

Hence, one is led to wonder if this is just another wrapper, or is this "the wrapper," for the human material is, as the authors acknowledge, too limited for conclusion.

The authors in full manuscript, which I have been privileged to read, have considered all this, in particular Dr. Campbell, who is an experienced nerve surgeon. They hope, and with good supportive data, that the special properties of this film may provide the mystical optimum conditions for nerve growth by protecting the suture line that other investigators have long sought. I hope so, too.

That is by Dr. Mayfield.

Dr. Henry C. Marble (Boston, Massachusetts): Most peripheral nerve injuries are to the upper extremities, very few in the lower extremities, and many come to us late because of failure of diagnosis. I would urge you to practice your neurology so that you may know the difference between median nerve, ulnar nerve and radial nerve paresis. The hand is entirely supplied in a motor way from the median and ulnar nerves; the sensation of the hand is almost to the front, as you know, by the median nerve the thumb, index, mid- and half the ring finger—it's all in the books. The back of the hand is supplied by the radial nerve.

Nerve tissue requires oxygen to live. It must have an adequate supply of oxygen to exist. We divorce the brain from its oxygen supply for four or five minutes and the brain ceases to function. We carry that out to the spinal cord and we separate the spinal cord from oxygen, maybe for an hour or a little bit more, and it ceases to function. How long a peripheral nerve will exist without an oxygen supply we don't know, but probably it's a matter of some days. To live, it must have oxygen, and it gets its oxygen through the blood.

The fundamental of nerve repair is to re-establish this proximal end to the distal end. That matter of re-establishment, from a surgical point of view, has gone through a multitude of processes. The first process I knew about was to suture it together and then wrap it in Cargile membrane. Most of you never heard of Cargile membrane. It was pig's bladder they used to wrap around it, and they thought they were doing a good job.

The next we had was the English method of sticking it together with cockerel plasma made into some sort of glue. I believe it was necessary that they should be cockerels; the hens wouldn't do. I don't know, but there must be something that sticks to a cockerel that doesn't apply to a female.

Anyway, they put the nerves together and they didn't suture them and then they wiped the joint around much as a plumber wipes a joint, and they thought that was a swell job.

I tried it, and I found that in the end my difficulty was in getting cockerel's plasma together in such a form that I could use it in the middle of the night when I was trying to sew up a nerve.

The next procedure was to do nothing, to let it alone. When the cut came, just leave it alone, see? Well, there it was. This was Seddon's idea. This end here? Nothing to it—and it's raring to go!

A nerve that is cut builds up a great big bundle of nerves that have no place to go, and there it sets and it hurts, and that is what you call a neuroma. The other end undergoes degeneration. This is the Seddon method, and I had disagreeable words with Dr. Seddon. He said afterwards they get some thickening of the neurolemma, so we tried it out in our cases that we had, and our cases that we sutured primarily were just as good as Dr. Seddon's.

Then, after that, came along a method of sewing it together and covering it with tantalum wire. I have heard a lot about how clever the surgeons in this war were and how dumb we fellows were in the first World War, but we didn't suture it and put tantalum wire around it because it violated every principle of healing. It turned off all the blood, and the darned things just degenerated. After it took them half of the war to learn that that was no good, they stopped doing that.

Then they all came back and, following sound surgical principles, we put the nerve together, something like that, and we brought the other one up and mated it. We then sewed the neurolemma here, very carefully together, and the best way that I can demonstrate it to you, we put the nerve together like this, and then we sutured it. Now that's an honest suture. You have got to do an honest suture anyway, and if you don't to that, then you have a couple of neurolemma sticking out like this, and another one like that, and when you get the job done you have a lateral neuroma and the patient has pain and he doesn't like it. That is the problem.

Now, here we come to the next step. All I say about this experimental work, in all affection, if he has a material which will aid our honest suture, which will hold it together, but at the same time will supply it with oxygen, as his pictures seem to show, then that is a step in advance. But if this system does not permit the introduction of extracellular fluids into that nerve, it is not good. You have got to get the blood in; you have got to have blood to heal.

How effective can it be? Experiments have shown us that to graft with large nerves you can't get blood into the center, so that we have had to reduce ourselves to using small nerves. In general I have used the tibial nerve out of the middle of the back of the leg and used multiple cables, so that I had many cables, and into those the blood could get, it could furnish it with oxygen and get regeneration.

The material can aid that good surgical operation. This is not a shortcut, as I see it, for surgery. This is an aid to good surgery. If that can aid in keeping the thing in line, furnishing the supply of fluid, it is a very helpful procedure.

HERNIATED LUMBAR INTERVERTEBRAL DISCS—AN ANALYSIS OF 1176 OPERATED CASES

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The surgical management of low back pain with sciatica gradually has been refined, since the contribution 26 years ago of Mixter and Barr (1). The differential diagnosis, selection of patients, and surgical technique have improved. Several notable contributions have been made by Love (2), Love and Walsh (3), Spurling (4), Echlin (5), O'Connell (6), Raaf (7), and many others. There are still certain problems to be solved. The question of fusion of the spine (posteriorly or by fusion of the bodies), more critical selection of patients for surgery, and the diagnosis with or without contrast studies should be clarified. Long follow-up studies are few in the literature. Ten and twenty year follow-up studies would be extremely valuable in answering some of the questions concerning the efficacy of the various techniques of management. Our present contribution involves a follow-up of four to fourteen years with 82% of the patients having been heard from or interviewed.

In 1948, we reported upon 196 patients operated on for low back pain with sciatic radiation, in a six year period from September, 1940 to September, 1946 (8). In the present paper, similar operative work within a ten year period from September, 1946, through 1956, involving 1176 cases will be analyzed, from the records of the Grace Hospital.

The material will be discussed under the headings of age and sex incidence, etiology, symptoms, signs, survey x-ray findings, myelographic evaluations, laboratory data, operative observations, post-operative complications, recurrences and results; cases with fusion and without fusion, also have been compared.

Age and Sex Incidence

In Table I, it may be seen that the majority of cases were between the ages of 31 and 50. Male patients represented 65.5% of the group. Under the age of 21 there were 13 examples. The youngest was a male 17 years of age. A little over 65% of the cases were between the ages of 31 and 50.

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Discussion of this paper is included with that of the following paper by Dr. Shumacker and associates.

TABLE I

Age and Sex Distribution

Decade	Male	Female	Total
0–20 Years	8	5	13
21–30 Years	111	53	164
31–40 Years	241	156	397
41–50 Years	260	122	382
51–60 Years	120	55	175
61–Plus Years	30	15	45
Totals....................	770 (65.5%)	406 (34.5%)	1176

TABLE II

Disc at Operation

(Not necessarily total spaces explored)

	L_5	L_4	L_3	L_2	$L_{4,5}$	$L_{3,4}$	$L_{3,5}$	$L_{3,4,5}$	$L_{2,3,4}$	No Disc		Total
L_5	113	79	0	1	33	2	1	1	0	11	*Narrowed Interspace by X-ray*	241
L_4	7	30	0	0	6	4	0	0	0	1		48
L_3	1	0	1	0	0	2	0	0	0	0		4
L_2	0	0	0	0	2	0	0	0	1	0		3
$L_{4,5}$	9	23	1	0	6	2	0	0	0	2		43
$L_{3,4}$	1	3	0	0	0	1	0	0	0	0		5
$L_{3,5}$	0	0	0	0	0	1	0	0	0	0		1
$L_{3,4,5}$	1	2	0	0	1	2	0	1	0	0		7
$L_{2,4,5}$	0	0	0	0	0	0	0	0	0	1		1
$L_{1,3,5}$	0	0	0	0	0	0	0	0	0	1		1
$L_{2,3,4,5}$	0	0	0	0	1	0	0	0	0	0		1
$C_{4,5}$	0	0	0	0	1	0	0	0	0	0		1

Etiology

History of injury in our group was elicited in about 35% of the cases. There were 93 with evidence of spondylosis in the group. Spondylolisthesis of varying degrees was noted in 20 examples. Narrowed interspaces were noted in 356 examples. In many, the narrowed interspace did not correspond to the level of the disc pathology. For instance, while in 113 patients who had a narrowed interspace at L_5-S_1 with disc protrusion at L_5-S_1, in 79 additional cases with an L_5-S_1 narrowing, there was a disc protrusion at L_4-L_5. Twenty-three patients had a narrowed interspace at L_4-L_5 and L_5-S_1 with disc disease only at L_4-L_5. Nine patients had a narrowed interspace at L_4-L_5 and L_5-S_1 with a disc at L_5-S_1. Eleven patients had a narrowed interspace at L_5-S_1 with no disc protrusion, (Table II).

Particularly in the young, the possibility of deforming spondylosis or Marie-Strumpell disease should be considered. This may be associated with low back

TABLE III

Symptoms and History

	Number of Patients	
History of injury	413	35.1%
Back pain	1158	98.5%
Increased pain with cough or sneeze	565	48.0%

TABLE IV

Radiation of Pain

Disc Level	Hip and Thigh	Knee	Leg	Foot	Flank Buttock Groin	No Radiation	Total
L_5	28	29	323	62	2	11	455
L_4	32	34	306	75	5	14	466
L_3	3	2	9	1		1	16
L_2		1	1			1	3
L_1		1					1
$L_{4,5}$	10	13	98	37	3	8	169
$L_{3,4}$	1	7	14	3		1	26
$L_{3,5}$	2		1				3
$L_{3,4,5}$	1		5				6
$L_{2,3,4}$			1				1
$L_{2,4,5}$			1				1
$L_{2,3,4,5}$			1				1
$L_{2,3}$	1			1			2
$L_{5,6}$						1	1
No Disc	5	1	11	3	1	4	25
Totals	83	88	771	182	11	41	1176

pain and sciatic radiation. In a few such cases, myelography was carried out and no associated disc protrusion or rupture was noted.

Symptoms

Low back pain was present in 98.5% of the patients. Increased pain on coughing or sneezing was noted in 565 examples representing 48% of the cases, (Table III). Radiation of pain into one or both lower limbs was seen in 1124 patients (Table IV), representing 95% of the cases. The radiation of pain as into the hip and thigh in 83 cases, all the way to the knee in 88, into the leg in 771 and to the foot in 182 cases. Radiations were typically described as being along the posterior lateral aspect of the thigh, posterior aspect and lateral aspect of the leg, into the foot.

Among 13 patients, there was a history of sphincter disturbance, (Table V). 10 patients had urinary retention and 3 had incontinence. Two patients had bilateral lower extremity weakness and saddle anesthesia. One had retention and the other was incontinent.

Physical Findings

In only 3.3% of the cases there were no definite findings, but merely complaints of pain in the lower back and in some, radiating pain in one or both extremities. On physical examination, these patients were found to be entirely negative.

TABLE V

Preoperative Sphincter Disturbances

	Retention		Incontinence
	Major	Minor	
L_5	3 1 had associated saddle anesthesia	2	1 with saddle anesthesia and paraparesis, 1 with CNS syphilis
L_4	1 with saddle anesthesia and paraparesis, 1 with CA of prostate, 1 with benign prostatic hypertrophy	1	1 with complaints associated with prior spinal anesthesia
$L_{4,5}$		1	
Totals.......	6	4	3

TABLE VI

Physical Findings in 1176 Patients

		Number of Patients	
No Findings..		39	3.3%
List..		257	21.9%
List to side of pain	73		
List away from side of pain	184		
Decreased motion of lumbo-sacral spine........................		658	55.9%
Tenderness over lumbo-sacral area.............................		290	24.6%
SLR positive—L_5	382	941	80.0%
L_4	375		
L_3	9		
L_2	1		
L_1	1		
$L_{4,5}$	137		
$L_{3,4}$	16		
Other multiple disc levels	8		
No Disc	12		

TABLE VII

Decrease or Loss of the Achilles Reflex

Disc Level	Same Side	Opposite Side	Bilateral with Unilateral Disc	Same Side Knee Jerk	Opposite Side Knee Jerk	No Decrease
L_5	255	10	3	23		164
L_4	93	8	1	14	4	346
L_3			1			15
L_2						3
L_1						1
$L_{4,5}$	47	5	1	8		108
$L_{3,4}$	5	1	1			19
$L_{3,5}$						3
$L_{3,4,5}$	3					3
$L_{2,3,4}$						1
$L_{2,4,5}$						1
$L_{2,3,4,5}$	1					0
$L_{2,3}$			1			1
$L_{5,6}$			1			0
No Disc	9			1		15

TABLE VIII

Decrease of Loss of the Patellar Reflex

Disc Level	Same Side	Same Side Ankle Jerk	Opposite Side	Opposite Side Ankle Jerk	Bilateral With Ankle Jerk	No Decrease
L_5	6	23	1			425
L_4	23	14	1	4		424
L_3	1					15
L_2	1					2
L_1						1
$L_{4,5}$		8				161
$L_{3,4}$						26
$L_{3,4,5}$						6
$L_{2,4,5}$						1
$L_{2,3,4,5}$	1					0
$L_{2,3}$					1	1
$L_{5,6}$						1
$L_{3,5}$						3
$L_{2,3,4}$						1
No Disc	2	1				22

Decreased motion of the lumbo-sacral spine was noted in 55.9% of the cases and a list was seen in 21.9%. List was to the side of the pain in 6.2%, and away from the side of the pain in 15.7%. Tenderness over the lumbosacral area was noted in 24.6% of the patients, (Table VI). This was elicited by either pressing against this area with the thumb or thumping against it with the fist or with a reflex hammer. There was a limitation of straight leg raising on one or the other side in 941 patients or 80% of the cases.

Foot drop was seen in 14 instances representing about 1% of the patients. Foot drop was associated with a protrusion at L_5-S_1 in 2 instances, L_4-L_5 in 2 examples and at L_4-L_5 and L_5-S_1 in 6 cases. One case of foot drop occurred with a disc at L_3-L_4 and L_4-L_5 and 2 cases of foot drop had no disc lesion present at operation.

Extensor hallucis longus weakness (dorsiflexion of the great toe), was present in 190 patients. Ninety-nine of these had an L_4-L_5 disc lesion, 54 had an L_5-S_1 protrusion and 29 had L_4-L_5 and L_5-S_1 discs. Foot drop was seen in 14 patients, (see above). Weakness of the other muscles in the lower limb was noted in 22 patients exclusive of those with extensor hallucis longus weakness, (Table IX). There were 4 peroneal, 1 anterior tibial, and 1 quadriceps weakness with L_5-S_1 disc lesions. There were 5 peroneal, 1 quadriceps, and 1 anterior tibial weakness with L_4-L_5 lesions. There was 1 peroneal weakness with L_3-L_4 and another with L_4-L_5 and L_5-S_1 lesions. There were 2 cases of peroneal weakness with L_3-L_4 and L_4-L_5, another with L_2-L_3, L_3-L_4, and L_4-L_5 lesions and in still another there was no disc lesion. The entire leg was weak in one case with L_4-L_5 disc lesions. In a case with lesions at L_3-L_4, L_4-L_5 and L_5-S_1, there was a weakness of all the calf muscles. In one case, there was atrophy of the thigh without a disc lesion, (Table X).

TABLE IX

Motor Deficits

	EHL Weakness	Foot Drop	Other Muscles	Bilateral Leg Weakness
L_5	54	2	6	1
L_4	99	2	7	1
L_3	1	1	1	
$L_{4,5}$	29	6	2	
$L_{3,4}$	4	1	2	
$L_{3,4,5}$	2		1	
$L_{2,3,4}$			1	
No Disc	1	2	2	

TABLE X

Motor Deficit—Other Lower Limb Muscles

Disc Level	Peroneal	Quadriceps	Anterior Tibial	Other	Total
L_5	4	1	1		6
L_4	5	1	1		7
L_3	1				1
$L_{4,5}$	1			1 (entire leg weak)	2
$L_{3,4}$	2				2
$L_{3,4,5}$				1 (all calf weak)	1
$L_{2,3,4}$	1				1
No Disc	1			1 (atrophy of thigh)	2
Totals.........	15	2	2	3	22

TABLE XI

Sensory Deficit

	Thigh and Knee			Leg		Foot			Saddle Anesthesia
	Post.	Lat.	Ant.	Post.	Lat.	Med.	M & L	Lat.	
L_5	2	11	1	7	51	18	7	111	2
L_4	1	14	2	3	45	62	8	37	1
L_3		1		1	3	2	1	1	
L_2			2						
$L_{4,5}$		5	1	1	10	11	4	23	
$L_{3,4}$					3		1	1	
$L_{3,4,5}$					1		1		
$L_{2,3}$		1							
No Disc					1	2		5	

TABLE XII

Survey X-Ray Findings

Spondylolisthesis	20
Spondylosis	93
Scoliosis	61
Spina Bifida	39
Spurring	119
Lumbarized S_1	24
Sacralized L_5	58
Facet Abnormalities	11
Loss lumbar curve	59

In 478 examples or 40.2% of the patients, some form of sensory abnormality was noted, characterized by hypesthesia, anesthesia or paresthesia.

In 118 examples of L_5 protrusion or rupture, there was sensory deficit along the lateral aspect of the foot, and the 4th and 5th toes. With L_4 abnormality, there was numbness on the dorsal aspect of the big toe and dorsum of the foot in 70 cases. Forty-five had numbness of the lateral aspect of the leg. The sensory changes were very rarely of a complete dermatomal distribution, (Table XI).

Severe deficits with weakness of both lower extremities and sphincter disturbance were seen in 2 cases. The number of cases with severe deficit is much lower in this group than in our group reported in 1948. There were 4 patients with severe deficit in 196 cases. This may be due to the fact that the ruptured disc syndrome is appreciated and diagnosed earlier at the present time than it was in the early forties.

Survey X-ray Studies

In Table XII, the x-ray findings have been analyzed. Spondylolisthesis of varying degrees was found in 20 patients, spondylosis was noted in 93 instances, and narrowed discs at one level or another were noted in 356. It may be seen in Table II that the level of the narrowed disc does not always correspond to the level of the ruptured or protruded intervertebral disc.

Thirty-nine examples of spina bifida were seen. Spurring was present in 119 patients and severe arthritis in 20. Six lumbar vertebra were present in 24 patients and sacralized 5th lumbar in 58. Facet abnormalities were reported in 11 cases. Loss of the lumbar curve was noted in 59 patients.

Myelography

Myelography was carried out in all patients, utilizing 6 cc. of pantopaque. Occasionally, 12 cc. of pantopaque was injected for proper visualization of the herniation or rupture. As may be seen from Table XIII, there was an accuracy of 84.6% at L_4-L_5. At the same level, a false negative of 8.4% was noted. At the level of L_5-S_1, the myelographic findings were accurate in 64.1%. There were 27.7% false negative and 8.2% false positives with lesions showing at this level. When disc protrusion or ruptures were found at both 4 and 5 interspaces, myelographic studies showed 39.9% positive at both levels and 52.1% at L_4 and 3.6% positive at L_5 only and .7% negative at both levels. Need for exploring both 4 and 5 whenever disc protrusion at L_4 is suspected is pointed out by the studies.

False negative myelograms for disc pathology at L_5-S_1 may be explained in part by the fact that the canal in this area is much wider than at L_4 and consequently a protrusion compressing the outgoing nerve may be in a lateral position without necessarily deforming the column of oil in the thecal cavity. In such cases, the definite neurological findings of lost Achilles jerk with sensory changes on the lateral aspect of the foot and the lateral one or two toes makes exploration desirable. False negatives at L_4 protrusion or rupture are few because the canal in this area is narrower and an abnormality in the vicinity of the outgoing nerve almost always compresses or deforms the myelographic column in the subarachnoid space.

We have always used myelographic studies thinking that in the absence of definite neurological abnormalities, a negative myelogram points to conservative therapy in a given patient. This has kept us from exploring patients whose complaints could be nervous in origin, who otherwise may have been explored with very poor results. In the presence of definite neurological abnormalities, myelographic studies are desirable since they localize the areas of involvement more accurately, (Table XIII). It is not unusual to find a lost Achilles jerk, for

TABLE XIII

Correlation of Myelographic Defects with Surgical Findings

Disc Level	Myelogram Positive Surgery Positive	Myelogram Positive Surgery Negative	Myelogram Negative Surgery Positive
L_6	1	0	0
L_5	400 (64.1%)	51 (8.2%)	173 (27.7%)
L_4	572 (84.6%)	47 (6.9%)	57 (8.4%)
L_3	49 (69.0%)	18 (25.4%)	4 (5.6%)
L_2	7	3	1
L^1	1	1	0

instance, with L_4-L_5 disc protrusion or rupture. On the basis of neurological examination alone, such a patient might be explored only at L_5-S_1, but on the basis of the myelographic studies, L_4-L_5 will also be explored, if the myleogram is positive. Myelographic studies also may disclose unsuspected abnormalities at higher levels.

Laboratory Data

Sedimentation rates were determined routinely, (Table XIV). There was an elevation in 192 cases. The elevation ranged from 10 to 108 mm. per hour. In a more recent series, we obtained sedimentation rates routinely also on the fifth post-operative day, (Table XV). It was noted that in 26 cases, the rate was elevated in patients who progressed satisfactorily with no serious complaints. On the other hand, in a certain number of patients who had severe pains after their operation, a sustained high level of sedimentation rate of 80 to 120 was noted. This was particularly true among patients who had aseptic necrosis of the vertebral body adjacent to the area of operation.

The spinal fluid total protein generally was not elevated in these patients. This may be partly due to the fact that in many of these cases, the spinal fluid was obtained from above the area of the disc pathology and consequently the fluid could not be expected to have a high level of protein accumulation as below the level of partial or complete block. In one series, an increase in total protein ranging from 40 to 119 was seen in 157 cases.

Recently, transaminase has been studied in the cerebral spinal fluid in patients with disc protrusion or rupture. These figures have not shown any unusual changes or variations from normal.

Routine blood studies in the majority of cases were normal. In 92 patients, there was an elevated white blood count ranging from 10,000 to 19,500. No other abnormality could be found which would explain the leukocytosis in these cases except in the patient with leukemia and a white count of 113,000. No evidence of leukemic infiltration was noted in the interspace. The patient had a bulging disc and his backache and sciatica improved after operation. The patient died two and a half years later from leukemia.

Operative Findings

Four hundred and fifty-five or 38.8% of the lesions were at L_5-S_1. Four hundred and sixty-six or 39% of the disc protrusions were at L_4-L_5. L_4-L_5 and L_5-S_1 combinations accounted for 169 or 14%. L_3-L_4 lesions were present in 26 cases or 2.2%. Other levels or combinations of levels are tabulated in Table XVI. In 25 examples, no disc protrusion or rupture was found. The area of exit for the nerve was found to be crowded by bony structure in 15 cases, sometimes associated with large venous channels. In a few instances, a completely calcified disc protrusion was noted. Decompression resulted in improvement. One case of thickened ligamentum flavum was noted and 1 lesion was accounted for by a lipoma involving the L_5- and S_1 roots. Four bilateral explorations were done; 2 at L_5-S_1 and 2 at L_4-L_5, (Table XVII).

TABLE XIV

Laboratory Findings

Elevated Protein		Elevated WBC's		Elevated SED Rate	
40 to 45 mg/100 ml	6	10,000 to 11,000	39	1 to 10	0
45 to 51	45	11,000 to 12,000	23	10 to 20	67
51 to 75	83	12,000 to 13,000	16	20 to 30	60
75 to 100	18	13,000 to 14,000	2	30 to 40	31
100 to 119	5	14,000 to 14,700	10	40 to 50	18
	—	19,700	1	50 to 60	8
	157	113,000	1	60 to 70	5
			—	75	1
			92	85	1
				108	1
					—
					192

TABLE XV

Sedimentation Rates—Tabulation of Pre- and Post-Operative Values

	Pre-operatively	Post-operatively
0–9 mm./hour	21	3
10–19	6	5
20–39	3	8
40–59	1	10
60–90	0	5

Of the male with elevation post-operatively (19), 16 or 84% had an uneventful course.
Of the females with elevation post-operatively (7), 5 or 71% had an uneventful course.
Normal Values: Male 0–9 mm./1 hour
Female 0–20 mm./1 hour

Patients in whom there was a sacralized 5th lumbar vertebra, 4th lumbar protrusion or ruptured disc could well cause combinations of findings suggesting an L_5 abnormality in the usual case with lost Achilles jerk and sensory changes along the lateral aspect of the leg and foot. In examples where the first sacral was lumbarized, the presence of a protrusion or a rupture of the intervertebral disc at L_5 interspace corresponded with the usual findings at this interspace.

The most common ruptured disc in this series was at the level of L_4-L_5. In our previous series, L_5-S_1 lesions represented 61% of the cases. However, there is a possibility that because of the greater bony space at the level of L_5-S_1, myelography may be negative, thus making visualization of L_5-S_1 involvement slightly less frequent than L_4-L_5 involvement.

In 41 instances, although the patient's myelographic defect was more marked on the side opposite the pain, the operation was carried out on the side of the pain. Apparent recovery frequently occurred and recurrences have been obtained in a few instances. In 2 cases, the side of the largest defect contralateral to pain was explored with good results.

TABLE XVI

Incidence of Ruptured Discs at Various Levels—1176 Patients

Level	Number of Patients
L_5	455
L_4	466
L_3	16
L_2	3
L_1	1
$L_{4,5}$	169
$L_{3,4}$	26
$L_{5,6}$	1
$L_{2,3,4,5}$	1
$L_{3,4,5}$	6
$L_{2,4,5}$	1
$L_{3,5}$	3
$L_{2,3,4}$	1
$L_{2,3}$	2
No Disc	25

Note: Two patients had bilateral lesion at the level of L_5
Two patients had bilateral lesion at the level of L_4

TABLE XVII

Findings in 25 Patients with No Disc at Operation

Root Decompression	13
Bony Intervertebral Bar	2
Thickened Ligamentum Flavum	1
Lipoma of L_5-S_1 Roots	1
Chronic Arachnoiditis S_1 Root	1
Negative Exploration	7
	—
	25

Five hundred and fifteen patients had a bulging annular ligament with soft sequestrated disc material beneath. Four hundred and ninety-four had a rupture of the annular ligament and a free fragment in the spinal canal was seen in 142 patients. An annular ligament found to be intact in the area of operative exposure does not necessarily mean that somewhat more medially the annular ligament may not be torn with posterior herniation of disc material. We are quite positive that this is true in many instances. In such cases, large sequestrated masses of material were removed from a more medial position in the interspace. Consequently, an intact annular ligament which is boggy on palpation, should be incised with exploration of the interspace.

Occasionally, the ruptured disc protruded between the outgoing root and the dural sac. The operative management of such a case becomes simpler when the surgeon realizes that the protrusion is in the axilla between the outgoing root and the dural sac.

The importance of visualizing the root canal in the exposure cannot be overemphasized. Ruptured disc material at times, is tucked away in the vicinity of the outgoing root, 1 or 2 cm. inferior and lateral to the interspace. During the inspection of the outgoing root, boggy masses and a presenting fibrous filament may point to a not yet removed mass of 1 to 4 grams of ruptured disc material. This can be easily teased out in the majority of cases.

The use of a curet is not permitted in our clinic since our unfortunate experience in 1947, traumatizing the inferior vena cava.

When the ruptured disc material is 1 to 2 cm. below the interspace, after the removal of the ruptured disc material, the interspace is also inspected. Frequently, there is a small rent in the annulus, but with most of it intact in the area of exposure. Incision of the annulus is carried out and the interspace emptied. In many instances, large sequestrated pieces of ruptured disc material may be removed by this maneuver. Presumably, this material could well extrude at a later date if it were not completely excised.

Lesions of the Upper Lumbar Region

Unilateral exposure may be dangerous in the upper lumbar area as a result of traction against the dural sac and the spinal cord. In so far as possible, the area should be exposed laterally, and as little pressure should be applied against the dural sac as feasible, to prevent damage to the spinal cord.

In cases with serious neurologic deficit and evidence of a block by myelography, transdural exploration through a full laminectomy may be desirable. This is particularly true when a lesion is in the upper lumbar area.

In the presence of many veins in the epidural space, electrocautery may be used with care. Cool saline should be irrigated in the wound as soon as the vessel has been cauterized. Careful separation of the bleeding vessel from the outgoing root is mandatory before the application of the current. When a vessel is bleeding from the lateral shelf of the hemilaminectomy opening, a blunt hook may be used to compress the vessel while the cautery current is applied to the conducting hook. We think that traction with a dural retractor may be more dangerous than the use of electrocautery in the interspace neighborhood in causing sensory or motor deficits.

In the performance of the hemilaminectomy, exposure laterally and inferiorly is extremely important. Particularly when there are adhesions about the outgoing nerve root, improper lateral exposure may result in a torn dura overlying the root. In so far as possible, no shelf of bone should be left in the lateral boundary of the hemilaminectomy opening. At times, the medial facet may be injured. If so, we prefer to excise it in its entirety.

If the dura is torn inadvertently, it should be repaired, if necessary by an exposure through a more complete laminectomy. Gelfoam or muscle does not adequately control a dural-arachnoid tear. If such a tear is not repaired, a large internal meningocele may form. We have had to repair two such cases in the past 15 years. Extrusion of cauda equina filaments through a dural tear may cause radicular pain.

Hemostasis seldom requires the use of gelfoam in the wound. Meticulous attempt in securing all bleeding points in the epidural area and in the muscles is mandatory before closing.

The material removed in these operations has been weighed (heaviest 13.5 grams). The usual amount is between 4.5 and 6 grams in weight. At times, removal of a small disc protrusion is associated with remarkable improvement in the patient's clinical condition. In other instances, large masses were removed without much improvement. In one case, a 12 gram mass was removed at the first operation and with no improvement in the patient's condition, three months later another 12 grams of material was removed from the same interspace.

Simultaneous Fusion of the Spine

Simultaneous fusion of the spine following the removal of the ruptured disc was carried out in 15.2% of the cases. The incidence of fusion varied from a high of 24.2% to a low of 9.3% in the various years between 1947 and 1956. Two of the orthopedic surgeons with whom we work fused every case of ruptured intervertebral disc. For other orthopedic surgeons, indications for fusion included mainly low back pain with no radiations or few attacks of radiating pains, heavy work and the presence of facet abnormalities, spondylolisthesis, spina bifida occulta and unequal lateral masses of the first sacral vertebra. A fusion in these patients was accomplished by the use of ilial bone being transferred to the lumbar region on the side opposite the exposed interspaces. Earlier, bone bank material was used. Infection rate average with fusion was much higher. Eight of 14 postoperative infections in this series occurred in the fused patients (8 of 179 cases). Of these, 3 patients had bone from the bone bank, 1 had a tibial graft, the remaining 4 were grafted with a section of the ilial border.

Post-Operative Complications (Table XVIII)

Two patients died. One had a tear of the vena cava with a massive retroperitoneal and intraperitoneal hemorrhage. This patient was re-operated and the inferior vena cava was found torn. The tear was repaired. Unfortunately, irreversible changes had already occurred and the patient succumbed in less than 24 hours. Cause of death in the other patient was a post-operative pulmonary embolism on the 8th post-operative day.

Aseptic necrosis was noted in 6 cases. Usually, the interspace bones become eroded. In one case, a discrete area of erosion disappeared within two months during convalescence, with little discomfort. In the other five, the typical course was characterized by severe post-operative pains with paravertebral muscle spasm. A high sedimentation rate was the rule. Convalescence was protracted and 4 to 10 months elapsed before a completely asymptomatic course was obtained. The lesion was identifiable by x-ray in 6 to 10 weeks rather than soon after the operation. In one case, exploration of the affected interspace was carried out. Tissue removed microscopically showed chronic inflammation. Grossly, the tissues appeared degenerated but nonpurulent with bone fragments and degenerated particles of tissue intermingled. These patients were treated by immobilization,

TABLE XVIII

Postoperative Complications

I. Infections	
A. Aseptic Necrosis	6
B. Wound Infection	14
8 with fusion:	
7—immediate post-operative drainage	
1—skin intact, bones degenerated	
6 with hemilaminectomy:	
5—immediate post-operative drainage	
1 dehisence	
2 massive infections	
2 stitch abscesses	
1—sinus 11 months later	
II. Foot Drop	3
2 with disc at L_4	
1 with disc at L_5 (all improved)	
III. Tear of Vena Cava-Death	1
IV. Massive Pulmonary Embolism-Death	1

antibiotics and supportive care. The use of cortisone in 2 cases did not materially help the course of their disease.

These 6 cases of aseptic necrosis had a good result subsequently. The explanation for the good result may be that the involved interspace is completely solid by fusion of the contiguous vertebral bodies, due to regeneration of bone. Possibly, this fusion is the basis for the good result manifested by these patients following a stormy convalescence post-operatively.

The bones adjacent to the interspace on the side of the operation usually manifest evidences of erosion and absorption. Occasionally, the absorption may occur at a distance from the interspace explored. In one of our cases, the interspace above the one explored was involved. In another, the side opposite the area of exposure was involved more so than the side which had been exposed. In some cases, more than two vertebral bodies may be involved and we are familiar with an example in which many of the vertebral bodies were degenerated but following this, regeneration of the bony tissues took place with restoration of the vertebral body contours. Three patients had a post-operative foot drop. All have recovered function. Foot drop is more likely to occur when traction is necessary in order to expose the interspace rather than by the use of electrocautery.

There were 14 wound infections. In 8 cases, a fusion was also accomplished by the use of ilial graft in 4, tibial graft in 1 and bone from the bone bank in 3 cases. All but one of this group had purulent discharge in the immediate post-operative period. Sequestration of bone occurred in 6 cases. One was explored and sequestrated bones were excised. In one case, the wound healed externally but x-ray evidence of bone absorption and inflammation was noted.

The other 6 cases of wound infection had only an exploration for the removal of a protruded disc. In one, a sinus developed 11 months later. The sinus was excised with complete healing. The other 5 had purulent discharge in the immediate post-operative period. Two had stitch abscesses; healing took place promptly after removal of the sutures. In one, there was a dehiscence of the wound. It was debrided and closed and healed satisfactorily. In two others, there was massive

TABLE XIX

Results on Patients with Over 9 Years of Follow Up

	Excellent	Good	Fair	Poor
10 years	25	29	15	3
11 years	21	40	16	2
12 years	16	28	11	6
13 years	8	15	3	0
Totals	70 (29.4%)	112 (47.1%)	45 (18.9%)	11 (4.6%)

TABLE XX

Follow Up Results

Non-compensation Cases		738 Cases
Without Fusion:		
Excellent	129	76.6% with Good or Excellent rating
Good	345	
Fair	112	
Poor	33	
	619	
With Fusion:		
Excellent	26	72.5% with Good or Excellent rating
Good	60	
Fair	23	
Poor	10	
	119	
Compensation Cases		177 Cases
Without Fusion:		
Excellent	25	61.5% with Good or Excellent rating
Good	69	
Fair	40	
Poor	19	
	153	
With Fusion:		
Excellent	4	50% with Good or Excellent rating
Good	8	
Fair	9	
Poor	3	
	24	

suppuration. One of these cases was debrided and closed with good healing. In the other, the wound was partly opened for drainage.

In our series, no paraplegia or severe paralysis of the extremities followed operation. No sphincter disturbances following surgery were noted.

Follow-Up Studies

Nine hundred and fifteen patients of 1176 were seen or heard from. Two hundred and thirty-eight of this group were followed up from 9 to 13 years, (Tables XIX–XXIV). Results were classified into excellent, good, fair or poor, according to their post-operative status at the time of follow-up. An excellent rating signifies no attacks of pain involving the back or the lower limbs with normal life following surgery. A good result signifies an occasional minor back discomfort but

TABLE XXI

Follow Up Results—Single Disc Lesions

Without Fusion:			
Excellent	131	21.0%	73.8% with Good or Excellent results
Good	329	52.8%	
Fair	124	19.9%	
Poor	39	6.3%	
	623		
With Fusion:			
Excellent	23	20.9%	72.7% with Good or Excellent results
Good	57	51.8%	
Fair	23	20.9%	
Poor	7	6.4%	
	110		

TABLE XXII

Follow Up Results—Multiple Disc Lesions

Without Fusion:			
Excellent	23	15.4%	72.4% with Good or Excellent results
Good	85	57.0%	
Fair	28	18.8%	
Poor	13	8.7%	
	149		
With Fusion:			
Excellent	7	21.2%	54.5% with Good or Excellent results
Good	11	33.3%	
Fair	9	27.3%	
Poor	6	18.2%	
	33		

TABLE XXIII

Follow Up Results—Multiple and Single Ruptured and Free Fragment Discs

Without Fusion:			
Excellent	96	21.4%	78.5% with Good or Excellent results
Good	256	57.1%	
Fair	69	15.4%	
Poor	27	6.0%	
	448		
With Fusion:			
Excellent	15	20.8%	66.6% with Good or Excellent results
Good	33	45.8%	
Fair	18	25.0%	
Poor	6	8.3%	
	72		

TABLE XXIV

Follow Up Results—Multiple and Single Bulging Discs

Without Fusion:			
Excellent	58	17.9%	66.7% with Good or Excellent results
Good	158	48.8%	
Fair	83	25.6%	
Poor	25	7.7%	
	324		
With Fusion:			
Excellent	15	21.1%	70.4% with Good or Excellent results
Good	35	49.3%	
Fair	14	19.7%	
Poor	7	9.9%	
	71		

not of sufficient magnitude to interrupt the daily activity or work. By fair, we mean a result associated with intermittent back discomfort which is not as severe as prior to surgery but still interfering with normal daily activity and work. Also, in this group are included patients who require a back brace for comfort. A poor result is one in which there was no improvement or there was a worsening following surgery.

In Table XX, the cases have been grouped according to compensation and non-compensation patients and with and without fusion. 76.6% of non-compensation patients without fusion had a good or excellent result. 72.5% had the same rating with fusion. Among the compensation cases without fusion, 61.5% had a good or excellent rating, while with fusion, 50% showed good or excellent rating. It should be noted that in some instances, fusion may have been done in patients who were poor prognostic possibilities.

In 238 cases, follow up of 10 to 13 years has been accomplished. It is interesting to note that 29.4% were excellent results, 47.1% good results, 18.9% fair results and 4.6% poor results.

DISCUSSION

Our criteria for operative intervention (including myelography) are: (1) recurring and incapacitating attacks of low back pain with or without sciatica which are progressive in severity and may or may not be associated with neurological deficits; (2) any apparent atrophy involving leg muscles in a patient with history of low back pain with or without sciatica; (3) definite neurological deficits in a patient with history of back or leg difficulty. For example, a definite weakness in extensor hallucis longus function which persists for more than a day or two, in our opinion is indication for surgical intervention. A patient of this type may develop a foot drop because of postponement of surgical treatment. (4) There is an occasional patient who presents with a surgical emergency due to a ruptured lumbar disc. Such a patient may be severely incapacitated with pain and may show associated sphincter disturbance as well as weakness and numbness of one or both lower extremities.

There are a number of conditions which may either mimic ruptured disc clinically, or may be associated with protrusion or rupture of lumbar intervertebral disc. Among these are such conditions as (1) spondylolisthesis, (2) spondylosis, (3) spondylolysis, (4) old fractures with deformity of the spine and subsequent compression of the neural structures. Other conditions may present a problem in differential diagnosis; these are peripheral vascular disease, diabetic neuropathy, cord tumors, malignancies of the spine. Similarly, any of the above may be seen concomitantly with ruptured disc disease, and, further, in the presence of some of these problems, the examiner is occasionally hard put to ascribe the clinical symptomology to one or the other condition. In general, if there is any suspicion at all of a surgical condition, and this would include cord tumor, spinal malignancy, as well as ruptured disc, we would prefer a myelographic study early rather than late. If the myelographic study is negative, conservative management is recommended. We feel that the low morbidity associated with myelographic study justifies this attitude.

In many instances even after repeated attacks of incapacitating back pain with or without sciatica, and in the presence of positive myleographic evidence of disc protrusion, the decision for surgery is still for the patient to make. This is particularly true in cases in which there is little or no clinical neurological deficit.

Conservative management of a patient with a lumbar disc syndrome includes such measures as pelvic traction, moist heat application to the lower back with massage, passive exercise, the wearing of a proper back support, the use of a hard or supported mattress in sleep, and anodynes. A proper evaluation of conservative management in an in-patient with a lumbar disc syndrome requires at least two weeks trial.

In instances where there is an associated spondylolisthesis, spondylosis, spondylolysis, orthopedic evaluation is always sought and then decision for conservative or surgical management is decided upon.

SUMMARY AND CONCLUSIONS

1) A series of 1176 cases of low back pain with and without sciatica, treated by operation, is analyzed. Sixty-five and one half percent were male. History of injury was obtained in 35% of the patients. The youngest in this series was 17.

2) Survey x-rays showed narrowed lumbar interspaces in 356 patients. In many, the narrowed interspace did not correspond with the level of the disc lesion.

3) Myelography was 84.6% accurate at the level of the 4th lumbar interspace. At the level of the 5th interspace, it was 64.1% accurate. False negative records were obtained in 27.7% with 5th interspace and 8.4% at the 4th interspace.

4) In 38.8% the 5th interspace was involved, in 40% the 4th interspace and the 3rd interspace was pathological in 2.2% of the patients.

5) In 515, there was a bulging disc, in 494 there was a tear of the annular ligament and in 142, a free fragment of disc material was found in the spinal canal.

6) Simultaneous fusion of the spine was carried out in 15.2%.

7) Post-operative complications included 2 deaths and 14 infections. Infections were more frequent in the fused patients—8 cases among 179 fused patients, contrasted with 6 infections among 997 patients with hemilaminectomy.

8) Follow-up studies were obtained in 915 patients. Excellent and good results were obtained in 76.6% of the non-compensation cases without fusion. Seventy-two and one half percent had the same rating with fusion. Among compensation cases without fusion, excellent and good results were obtained in 61.5%, with fusion excellent and good results in 50% of the patients.

BIBLIOGRAPHY

1. Mixter, W. J., and Barr, J. S.: Rupture of the Intervertebral Disk with Involvement of the Spinal Canal. New Engl. J. Med., 211, 210, 1934.
2. Love, J. G.: Protruded Intervertebral Disks with a Note Regarding Hypertrophy of Ligamenta Flava. J.A.M.A., **113:** 2029, 1939.
3. Love, J. G., and Walsh, M. N.: Intraspinal Protrusions of Intervertebral Disks. Arch. Surg., **40:** 454, 1940.
4. Spurling, R. G.: Lesions of the Lumbar Intervertebral Disc. Charles C Thomas, Springfield, Illinois, 1953.
5. Echlin, F. A.: in Injuries of the Brain and Spinal Cord and their Coverings. Brock, S., Springer Publishing Company, Inc. New York, Fourth Edition. Chapter 21, 602–674.
6. O'Connell, J. E. A.: Protrusions of the Lumbar Intervertebral Discs. A Clinical Review Based on Five Hundred Cases Treated by Excision of the Protrusion. J. Bone & Joint Surg., **33B:** 8–30, 1951.
7. Raaf, J.: Some Observations Regarding 905 Patients Operated upon for Protruded Lumbar Intervertebral Discs. Amer. J. Surg., **97:** 388–399, 1959.
8. Gurdjian, E. S., and Webster, J. E.: Lumbar Herniations of the Nucleus Pulposis. An Analysis of 196 Operated Cases. Amer. J. Surg., **76:** 235–243, 1948.

VASCULAR COMPLICATIONS FROM DISC OPERATIONS

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During the past fifteen years a number of very informative papers have appeared in the literature concerning vascular injuries incurred inadvertently during operations upon herniated discs. The recent paper of DeSaussure (1) would indicate that such accidents occur considerably more frequently than one would have previously assumed to be the case. His study is based upon answers to a questionnaire sent to over 3,000 neurologic and orthopedic surgeons and a survey made from the answers received from a high proportion of those sent out. A total of 106 vascular injuries were thus reported. These included injuries to the aorta, the common iliac, the external iliac and the hypogastric arteries, to the vena cava, the common iliac vein and to smaller vascular channels.

Data were obtained regarding the time of recognition of the vascular injury in 101 instances. In 47 the injury had been recognized at once, but in 54 it was not. In these same cases there was bleeding from the interspace in 43 and no significant bleeding in 58. In 11 cases the time of operation for the vascular injury was not stated. The mortality in this group was 49 per cent. In an additional 23 cases no operation for the vascular injury was performed and all of these patients succumbed. The time of operation was cited in 69 instances. The injury was recognized early and early operation was carried out in 31 with a 24 per cent mortality. It was recognized early but operation was carried out more than 24 hours after injury in 5 instances with 2 deaths. It was recognized rather late but early operation was performed in 14 with a 50 per cent mortality. In 19 instances the injury was recognized late and operation was carried out more than 24 hours after injury with a mortality of 16 per cent. Arteriovenous fistulas were produced between the aorta and vena cava or between the common iliac artery and vein in 13 instances and all save one of these patients recovered. It was of interest that 91 vascular injuries were reported in patients operated upon under general or spinal anesthesia and only 4 such injuries in patients operated upon under local anesthesia. It is to be hoped that studies of this sort and the other excellent papers which have called attention to this catastrophic surgical accident will do much to prevent its occurrence and will lead to proper management when this complication does arise.

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Aided by a contract between the Office of Naval Research, United States Navy, and Indiana University.

Useful information can often be derived from a careful analysis of a few pertinent cases and it is the purpose of this report to describe three cases which we have treated for such complications.

Case 1. The first case was a 32-year-old female who was admitted to our hospital in March 1955. She had been operated upon in June 1953 in another institution for a protruded intervertebral disc. She developed some shortness of breath postoperatively and shortly after discharge from the hospital complained of swelling of her lower extremities which was worse on the left side. In July she was readmitted to a hospital and treated for 6 weeks with a diagnosis of thrombophlebitis. While hospitalized she received 5 transfusions. In August she noticed swelling of her abdomen, and within a few weeks, of her lower extremities, arms and face, associated with nausea, vomiting, dyspnea and obvious gain in weight. She had to be rehospitalized in November because of profound heart failure. She was so edematous that she could not get out of bed and so orthopneic she had to sleep sitting straight up. She was treated with diuretics, ammonium chloride and digitalization with some improvement. The ascites, however, persisted and by January 1954 she had to have a paracentesis because she was so extremely dyspneic. Eight subsequent paracenteses were necessary because of the tremendous abdominal swelling and dyspnea. In spite of medical management, she continued in a state of marked chronic heart failure. She became progressively more restless, irritable, and somewhat confused and so depressed that early in January she attempted suicide. She was admitted to a psychiatric hospital.

The diagnosis of arteriovenous fistula was apparently not made until she was admitted to our hospital in March 1958, nearly 3 years after her original opera-

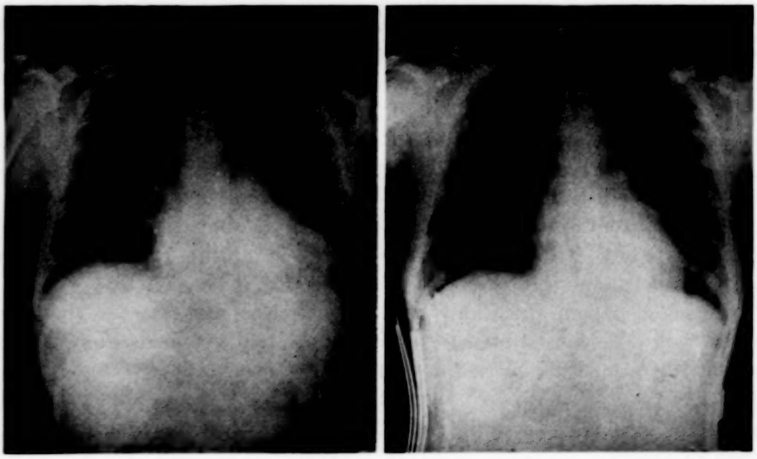

FIG. 1. Photographs of roentgenograms showing the cardiac enlargement before and reduction of heart size shortly after operative resection of the arteriovenous fistula in Case 1.

tion. At this time she was in extreme heart failure, dyspneic and orthopneic. She was edematous, and had ascites, marked hepatomegaly and splenomegaly, pronounced cardiac enlargement and a wide pulse pressure. The blood pressure was 130/20. In addition, there were tell-tale evidences of an intra-abdominal arteriovenous fistula with a loud continuous murmur. X-ray studies showed a very large heart with increased bronchovascular marking in the lungs. (Fig. 1) An electrocardiogram was not remarkable except for evidences of digitalis effect.

She was operated upon on April seventh. A great deal of ascitic fluid was present. There was an aneurysm of the proximal portion of the right common iliac artery about 3.5 centimeters in diameter interposed between a short proximal segment and the longer distal segment of this vessel. There was an opening from the aneurysm about 2 by 1-½ centimeters in size directly into the vena cava. The aneurysm was excised and the opening into the vena cava closed by direct suture. A plastic graft 3 centimeters in length was interposed between the two ends of the common iliac artery.

The patient made an uneventful recovery and the cardiac symptoms rapidly disappeared. She was soon up and about with no dyspnea, ascites, orthopnea nor peripheral edema. She was discharged from the hospital on the seventeenth postoperative day. At this time she had no complaints, could walk up stairs with ease and her blood pressure was 142/90. Diuresis had occurred shortly after operation and when she returned to the outpatient clinic 5-½ weeks after operation she weighed 129 pounds. She had lost 86 pounds since the time of surgical treatment! She was followed for three years and continued to be free of cardiac complaints. Unfortunately, she gradually became obese and continued to have the same symptoms in her left lower extremity for which the disc operation had originally been carried out.

Comment: This is an example of a tragic late recognition of the vascular injury and late operative correction of the resultant arteriovenous fistula. It is of interest that she sustained an injury not only of the common iliac artery but of the vena cava as well, with the production of an arteriovenous fistula. The expected higher survival rate in cases of concomitant venous and arterial injury with production of a fistula is borne out by the survey of Dr. DeSaussure and other reports such as that of Harbison. (2) In the first place, blood loss immediately after the injury is likely to be minimal if an arteriovenous fistula is produced since blood lost from the artery readily passes back into the patient's own blood stream via the low pressure venous system. Thus early death is less likely to occur from exsanguination. In the second place, decompression of any resultant traumatic aneurysm into the low pressure venous system makes unlikely late rupture with death from bleeding. It is, of course, important to recognize the fistula as soon as is possible and to carry out effective surgical eradication in order to avoid the consequences so dramatically manifested in this case. This poor lady had years of profound disability necessitating tremendous economic loss and several needless periods of hospitalization because of the late recognition of the fistula. Actually, the occurrence of a traumatic arteriovenous fistula should be recognized with considerable ease because of the continuous bruit which accompanies it.

Case 2. This patient was a 33 year-old male who was operated upon for a protruded intervertebral disc on May 6, 1956, at our Veterans Administration Hospital. The right fifth lumbar and first sacral lamina were exposed. A hole was found in the annulus and a degenerated disc was removed. Only moderate bleeding occurred and this was easily controlled with gelfoam. A pituitary rongeur was used. The operator stated that no resistance was met when the rongeur was passed through the anterior longitudinal ligament and it was his feeling that a defect was already present in this area. Recognizing the possibility of vascular injury, the operative site was watched carefully and no active bleeding was encountered. The patient had, however, lost a great deal of blood during the initial part of the operation because of epidural bleeding and altogether 2500 cc of whole blood were given. He complained of some right lower quadrant pain and tenderness postoperatively. He also had evidence of some paralytic ileus. On the third postoperative day while straining at stool, he suddenly went into shock and no pulse or blood pressure was obtainable. He was quickly given a liter of Dextran, 500 cc. of whole blood, and taken to the operating room. There was some serosanguinous fluid free in the abdominal cavity and a large retroperitoneal hematoma in the pelvis. The aorta was quickly exposed and temporarily occluded. There was no injury to the left iliac artery but active bleeding in the region of the right. On further dissection, it was found that the injury had occurred in the proximal portion of the hypogastric artery. This was ligated proximally and distally. The hole in the anterior annulus could be readily palpated in this area. Fifteen hundred cubic centimeters of blood were administered during the operation and he recovered uneventfully.

Comment: In this instance though the patient recovered, he had a close call because of the delay in recognition of the vascular injury. In spite of the fact that this possibility had been considered by the operator at the time of the disc surgery, the absence of bleeding following passage of the rongeur through the anterior annulus had given him a sense of false security. The diagnosis, tragically enough, was not made until the patient was in profound shock and pulseless on the third postoperative day. In retrospect, it would seem evident that the complaint of right lower quadrant pain and tenderness and signs of paralytic ileus shortly after the original operation should have prompted investigation at that time. Either an arteriographic study or exploratory operation would have resulted in disclosure of the traumatic iliac aneurysm prior to its rupture and the near exsanguination of the patient. They could have been carried out with the patient in good condition instead of in a state of complete circulatory collapse. It is well known that injury to an artery produces a traumatic aneurysm which may remain relatively small for a period of time and be attended with relatively little loss of blood only to be followed after an indeterminate interval with rupture and profuse loss of blood. Repair should be carried out before the latter occurrence. It should also not be forgotten that the ureter may be injured during a disc operation.

Case 3. The patient was a 35-year-old male who was admitted to the hospital on October 2, 1959. For three weeks he had been unable to move his right lower extremity and had complained of severe pain. Though he presented a difficult diagnostic problem, the diagnosis of a herniated disc was ultimately made and he was operated upon on October 16. A laminectomy was carried out at the fourth lumbar level and the upper portion of the fifth and inferior portion of the third lamina were removed. There was a fifth lumbar midline herniation with extension to the right side extradurally. After the disc was removed the instrument suddenly dropped through the anterior annulus and on withdrawal there was a spurt of blood. The area was quickly packed and the wound closed with clamps. Meanwhile, the pressure had dropped precipitously from 125/75 to 80/50. A transfusion was begun immediately, the patient turned, and surgical consultation was obtained without delay. A low left thoracotomy incision was made and a midline incision started shortly thereafter. The thoracic aorta was temporarily occluded while the midline incision was completed. There was a huge retroperitoneal hematoma. The aorta was promptly dissected free and occluded with a non-crushing vascular clamp. The thoracic aortic occlusion was simultaneously released. On further exploration it was found that there was a laceration of the left common iliac artery 2 centimeters below its origin from the aorta. It was occluded above and below, the aortic clamp released, the damaged portion of the vessel resected, and an end-to-end anastomosis was carried out. During this procedure there was a measured blood loss of 1200 cc. Fifteen hundred cubic centimeters of blood had been given before the patient had been turned and another 500 were administered during the abdominal operation. The patient recovered uneventfully, had good restoration of pulses in the left lower extremity, and has continued to make progress with regard to his left lower extremity paralysis.

Comment: In this instance the vascular injury was recognized immediately after its occurrence and prompt treatment was carried out. It is obvious that this is the desirable sequence of events and it is unlikely that this patient would have survived had not the bleeding been controlled so soon and blood replacement carried out so promptly. Though many such cases could be managed successfully without temporary operative occlusion of the distal thoracic aorta, we are inclined to believe that this maneuver adds an element of safety. This opinion is based largely on experiences with the operative treatment of ruptured abdominal aortic aneurysms. When there is a large retroperitoneal hematoma, with or without intraperitoneal hemorrhage, one often finds it difficult to isolate the aorta proximal to the point of leak without getting into the hematoma and incurring further blood loss. Such hemorrhage is obviated by the temporary occlusion of the distal thoracic aorta and ordinarily the abdominal incision, and isolation of the abdominal aorta can be accomplished so rapidly the thoracic aorta need be occluded only 10 or 15 minutes.

DISCUSSION

It is felt that these three cases illustrate the major problems involved in recognition and surgical management of vascular lesions resulting from disc operations. The vascular injury will, of course, be easily recognized as in the third case when profuse bleeding occurs through the anterior annulus associated with evidences of hemorrhagic shock. In any patient in whom there is any suspicion of vascular injury at the time of a disc operation, as in the second case, the possibility should be investigated shortly thereafter. Arteriographic study or exploratory laparotomy should be carried out depending upon the clinical findings. When evidence of a vascular injury is scant, aortographic investigation would be the procedure of choice. This can be accomplished either by percutaneous puncture of the aorta or by retrograde injection of dilute hypaque into the femoral artery using a pressure injector and with tourniquets excluding circulation from both lower extremities. If there are more suggestive evidences of a vascular injury such as the right lower quadrant pain and tenderness noted in our second case, one might well proceed with exploratory laparotomy. The thing to be avoided is both late recognition and late treatment as exemplified by the first case. In this instance there was an arteriovenous fistula which threatened the patient's life because of the consequent heart failure rather than by danger of hemorrhage. When an arterial injury alone has been incurred, late treatment is inadvisable because of the constant threat of rupture of the traumatic aneurysm with fatal exsanguination. To be sure, as was true in the survey of DeSaussure, the mortality should tend to be low in instances of late recognition and treatment provided the operation is carried out for an arteriovenous fistula or a false aneurysm prior to rupture.

REFERENCES

1. DESAUSSURE, R. L. Vascular injury coincident to disc surgery. J. Neurosurg., **16:** 222, 1959.
2. HARBISON, S. P. Major vascular complications of intervertebral disc surgery. Ann. Surg. **140:** 342, 1954.

DISCUSSION

DR. ROBERT MAZET, JR. (Los Angeles, California): I feel that I am the wrong man in the wrong place at the wrong time with the wrong material.

Several years ago we had two boxers in our house. They got along quite well for some time, but eventually they decided to disagree quite heartily, and on one occasion when there were visitors in the house they had a session in the middle of the living room. My wife started raising a little fuss and said, "Do something! Do something!" So I grabbed both dogs, one with each hand, and the result of it was that I received a great big scar on my thigh which I can show today. So I found myself in the middle of that one, and I'm in the middle of this one, and I hope I get no scars today.

Up in Oregon they have a lovely river called the Rogue—beautiful trout fishing in the summer, steelhead fishing, and so forth—so my wife took me up there to fish a couple of weeks ago. While I was gone a letter came from Paul Harmon: "I have to go to South Africa. Will you discuss my paper?"

My secretary was a little perturbed about this. She didn't know exactly how to get hold of me, but my friend Mason Hohl said, "Well, tell them if Mazet doesn't discuss the paper I will." so she felt better and said, "Yes," and pretty soon along came a letter from Paul Harmon with a discussion which started out something like this: "To discuss these erudite papers in three minutes is an almost impossible task", whereupon he wrote a twelve-minute discussion, so I have summarized his discussion, which I will now give.

It is difficult in all cases to localize the level of the lesion in these disc syndromes. They may be multiple. In addition to the usual careful physical examination and laboratory studies, including spinal taps, myelograms are almost a necessity, and he says that people have now come around to believing that in most instances.

In addition to this, as you probably know, he has a little technique that he uses on the operating table, of injecting saline into these intervertebral disc spaces, and if too much saline goes in he thinks there is something wrong in the disc into which it goes.

Then he will without any hesitancy do an adjacent disc if he thinks it is "degenerated." I am not quite sure what he means by "degenerated," but apparently he does quite a few exposures of more than one disc space, and he says that this is particularly true if the myelogram has shown a lesion at the L-4 level. He very frequently, apparently, explores the disc at the L-5 level too.

He advocates inter-body fusion, as you know, if the people have had any previous disc surgery, and he apparently does not entirely agree with some of the ideas of the first speaker this afternoon. He says that he is very happy with the good percentage of results that the second speaker has obtained, and he thinks that this reinforces his plea for accurate diagnosis before operation.

He admonishes the surgeon to look out for such as the arteriovenous fistula, which the third speaker just mentioned, and he stresses the necessity for care in dealing with the anomalies of the vessels which may be encountered in the anterior side of the lower lumbar level in doing these anterior fusions. He also admonishes the surgeons to be on the lookout for any anatomical variations, bony projections and scar tissue, which the first speaker mentioned.

PRESIDENT STACK: Dr. Gurdjian, I would like to ask, do you consider the myelogram a diagnostic or a confirmatory test? Sometimes we have a feeling that in our part of the country the myelogram is abused. Also I would like to ask you, why do some people with proven herniated discs list away from the side of the lesion while others list toward the side of the lesion?

DR. RALPH G. CAROTHERS (Cincinnati, Ohio): If I can read Dr. Mayfield's discussion, which has come by one of these very fancy telegrams of four or five pages, it says:

"To discuss adequately these important papers within three minutes 'in absentia' is not easy. To Dr. Gurdjian and his colleagues, I would extend especial compliments. It has been my privilege to read in detail the entire manuscript of the magnificent study which has been briefed for you. This is the most complete long-term follow up study of a large series of patients with lumbar disc disease that I have seen.

"It is characteristic of Dr. Gurdjian and his group, I think, to have prepared and maintained records that would permit answering the many searching statistical questions in 82 per cent of the 1176 cases treated surgically in one hospital. It is from such studies as this, which unfortunately are not possible in most plans, that the most important of the factors contributing to failure in surgery will be found.

"There can be little doubt that the low back imposes problems both at surgery and in rehabilitation whether there is an abnormal disc or not. We agree with the great necessity for putting the patient properly on the table and with proper anesthesia to avoid the difficulty that occurs when the epidural plexus is distended by obstruction.

"There is no room for disagreement in anything that Dr. Schumacker has said, yet I would emphasize that now that the hazard of injury to the large abdominal vessels during the removal of an herniated intervertebral disc is known, it should not occur again. Dr. Gurdjian states that he does not permit the use of a curette in his clinic for fear of injury to the great vessels. I would emphasize, however, that it is not the curette but the inexperienced curetter who should be eliminated. On our service the abdomen has been entered accidentally by this route on two occasions. The first occurred just after World War II and resulted in a wound of the iliac artery. The instrument was a pituitary rongeur. The vessel was repaired through a laparotomy three hours later. The operator was not aware of the hazard of abdominal vascular injury and did not recognize the error at the table. There was no doubt, however, that the jaws of the forceps were closed on the vessel.

"On the second occasion, a more experienced operator recognized that the instrument was in too deep and withdrew it without biting. Since then, every operator assures himself by measure that the curette or rongeur is in the interspace and not beyond into the abdomen before applying force.

"The reasons for my absence are known to the President, but I would ask Dr. Carothers to extend my apologies and personal regrets to the essayists and to the assembly."

I personally would like to say one word with regard to one point that was brought up by Dr. Gurdjian, and that is the very much worse result in the compensation case. There is a factor in behalf of the patient, and that is the number of employers who will not employ a man with a scar on his back.

Dr. E. S. Gurdjian (Detroit, Michigan): In answer to Dr. Stack's questions, I may say that we use the myelogram both diagnostically and for confirmation, but we do find that the judicious use of the myelogram makes it possible for us to refuse operation in a great many cases that otherwise would be difficult problems in management.

I think that if a myelogram is negative or nearly negative, or equivocal, conservative therapy for another six months will do no harm. It is probably better among some of these cases to procrastinate since some backaches are similar to a tension headache. Tension headaches and pressure headaches may be very difficult to cure, as you know.

A list away from the lesion makes the interspace somewhat wider on the side of the lesion with greater space in that area, and therefore possibly less pain. Occasionally, however, the patient may list to the same side, and this may be due to muscular contractions in the vicinity of the involved nerve in such a manner as to immobilize the structures and keep the patient from developing pain on the slightest motion. Possibly the compression under these circumstances may have a little anesthetic effect upon the outgoing root.

Dr. Carothers' statement about compensation and noncompensation cases is, of course, very well taken. In Detroit, where there are a great many compensation cases—and you will notice that there are quite a few patients with compensation problems in our reported series—rehabilitation may depend on the attitude of the employer. Some will say, "Do not come back until you are 100 per cent." Others will make an attempt to get this man back and have him carry on at his previous work and pay.

With some companies we have been able to return patients with compensation problems back to work with very few exceptions, whereas in other instances, where the company is unable to care for these people, there has been a great deal of difficulty in getting them back to work. This factor is indeed a problem.

TEN YEARS' EXPERIENCE WITH PENETRATING INJURIES OF THE HEART

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Standard operative approaches to most organs have been developing for many centuries; however, it is only comparatively recently that the barrier offered by the pericardium has been passed (7). Four hundred years ago the French surgeon, Paré, claimed that wounds of the heart may heal. One of the earliest methods of therapy for cardiac injuries was suggested by Riolanus (18), who in 1649 advocated pericardial aspiration. Larrey (13), in 1829, reported spontaneous recovery of cardiac injuries following aspirational therapy. In 1881, Roberts (19) first suggested direct suture of heart lacerations, and one year later Block performed such suturing in the experimental animal (5). In 1868, Fischer (10) reported 452 cases of cardiac injury treated by aspiration and venesection with a fatality of 84 per cent. Successful cardiorrhaphy in the dog was performed by Del Vecchio (9) in 1895. The same year, Cappelen (6) performed an unsuccessful cardiorrhaphy in the human. The following year, 1896, Rehn (17) of Germany performed the first, successful, human cardiorrhaphy.

In the ensuing years, many individual studies have been presented illustrating the two major methods for treatment of cardiac injuries; simple aspiration of the pericardial sac as opposed to direct surgical repair (2, 3, 4, 12, 14). To this controversial subject we would like to add our experience in 102 cases of cardiac trauma during the period 1949–1958.

Material

The case histories of all of the patients of the City of Detroit Receiving Hospital in whom the diagnosis of penetrating cardiac injury was made, in the years 1949–1958, and who were alive on admission, are included in this review. It does not contain an estimated 10 cases from the year 1951, whose records are lost. In all, there were 102 documented cases of traumatic penetrating cardiac injuries admitted to the Detroit Receiving Hospital during this 10 year period. The usual history, physical, laboratory studies and diagnostic studies such as x-ray, fluoroscopy notes and electrocardiograms, were all available for review.

The City of Detroit Receiving Hospital is a University affiliated, municipal hospital. In keeping with teaching responsibilities, all surgical therapy is carried

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Discussion of this paper is included with that of the following paper by Dr. Beall and associates.

Aided in part by grants from the Michigan Heart Association, the National Institutes of Health (H-3465 (C2) and H-2553 (C3)) and the Receiving Hospital Research Corporation.

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out by the resident surgical staff. This particular clinical entity is usually the responsibility of a resident surgeon at the fourth year level of training, under the direction of a staff surgeon. Under this system, of the 102 cases, no more than 6 were operated upon by any single individual.

Diagnostic and Therapeutic Measures

The classic triad of Beck, the large, quiet heart, associated with an elevated venous pressure, has been used as the sine qua non of cardiac tamponade. Sphincter incontinence is another frequent sign. It goes without saying that those cases of cardiac injury in which decompression occurred into either hemithorax require further diagnostic procedures for aid in diagnosis. Admission x-ray films of the chest, postero-anterior and lateral, are obtained. These frequently aid in demonstrating an unsuspected pericardial fluid accumulation with or without concomitant hemothorax. Fluoroscopic observation of cardiac pulsations is performed when conditions warrant, its utilization being a matter of surgical judgment dependent upon clinical appraisal of the patient. Pericardial aspiration, prior to other studies, is another valuable procedure, most helpful when positive, and of little or no significance when negative. It is of prime therapeutic importance in immediate therapy of acute cardiac tamponade.

Intravenous fluids are begun immediately upon admission. Simultaneously, blood is obtained for CBC, and typing and cross matching. The rationale for immediate intravenous infusion preceding pericardial decompression is based upon the work of Cooper, Stead and Warren (8), who have shown increased ventricular filling with elevated venous pressure. In cases where the patient's condition demands, O negative blood is given on admission. The remaining pre-operative preparation is identical with established routines.

Data

The instrument used in creating cardiac injury was most commonly the knife in our series. There were 90 stab wounds due to knife trauma, 9 cases in which an ice pick was used, and 5 gunshot wounds. Ninety-six were males and 6 females; of this group 88 were Negro and 14 were white.

In this series of 102 cases, the age distribution pattern follows a nomogram. The peak incidence of cardiac injury occurred in the 31–40 year old age group. The extremes of age are respectively 15 years and 76 years.

Using the previously described criteria, Beck's triad (1) was present in 49 cases, absent in 40 and unknown in 10. Acute tamponade judged to be present on clinical grounds occurred in 50 cases, was absent in 42, and unknown in 10. The 42 cases in which acute tamponade was judged not to be present are those in which pericardial decompression into the thorax occurred, the intrapericardial blood had coagulated, those who had hemopericardium on x-ray study, or in whom hemopericardium was only detected at operation. It is the first of these groups of patients who are the most urgent emergencies. The very real danger of exsanguination exists in these cases and these are also, unfortunately, those in whom the physician may be lulled into a false sense of security based upon negative pericardial tap, normal sized heart, good heart tones and normal or subnormal venous tensions (14, 16).

Pericardial aspiration was performed on 59 patients on admission to the hospital (either as a diagnostic or as a therapeutic procedure). Aspiration was not done in 41 cases and was unknown in 2 cases. The usual infraxiphoid or transthoracic routes were employed. When it was not attempted several factors came into play. There were cases without tamponade in which the diagnosis was obvious, such as massive external arterial bleeding through the chest wound and moribund cases that were taken to the operating suite pausing only long enough to begin intravenous infusion. Of the 59 aspirations performed, 44 or 75 per cent were positive. Three individuals in this group underwent repeated pericardial aspiration. In our series few patients maintained a satisfactory clinical course even with repeated aspiration. The mechanism of physiologic benefit of pericardial aspiration for acute tamponade is well documented elsewhere (1, 2).

X-Ray examination was performed on 75 cases prior to definitive therapy. The most common single finding was that of hemothorax which occurred in 24 cases. Cardiomegaly was noted in 36 cases; 20 of these were thought due to hemopericardium with the typical water bottle shape. The remaining 16 cases of cardiomegaly were interpreted by the radiologist as being due to causes other than intrapericardial fluid. Fluoroscopic examination was undertaken in 20 cases, and demonstrated decreased cardiac pulsation in 11.

The time interval between diagnosis of penetrating cardiac trauma and operation varied from 3 minutes to more than 3 hours. The interval was influenced by the time spent at x-ray, fluoroscopy, in other diagnostic efforts. There were several cases in which the elapsed time was less than five minutes, while there were 17 in which the interval was greater than 3 hours; 2 cases were operated upon after an unknown interval of time. In review of these cases, we have been unable to relate the elapsed time from admission to operation with case fatality.

Using the previously described criteria of Beck's triad, positive pericardial aspiration and/or radiological confirmation of cardiac injury, a total of 92 cases were operated upon. The distribution of cardiac wounds as determined by the surgeon at the time of cardiorrhaphy is illustrated in Figure 1. The following lesions were associated with one or more of the 39 cases of right ventricular intraluminal laceration: a through and through laceration also involving the left ventricle; an associated laceration of the anterior circumflex coronary artery; in 3, injury of the internal mammary artery of the same side; and in another, associated injury of the right auricle.

Thirty-seven cases of intraluminal left ventricular penetration were encountered. In this group we found one in which the anterior descending coronary vein was lacerated and another with injury of the anterior descending coronary artery. Two patients had 2 separate left ventricular lacerations, only 1 of them intramural and nonpenetrating.

There were six right auricular injuries, 1 with an associated internal mammary artery injury, another with a nonpenetrating intramural injury, and a third with 2 individual lacerations of the right auricular wall.

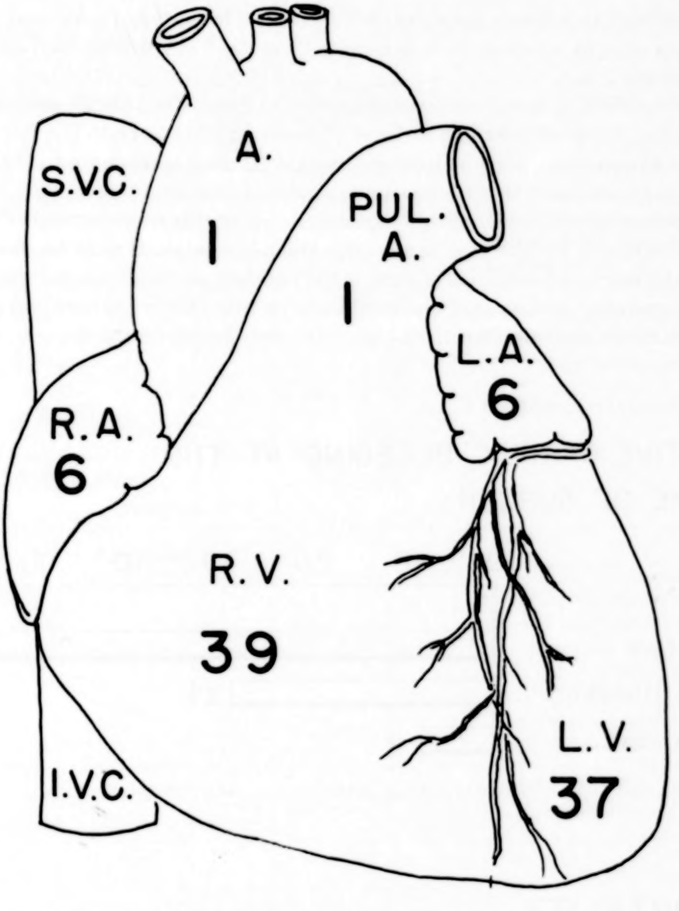

FIG. 1. Location of cardiac wound

The last series is that of 6 left auricular intraluminal injuries. In this group one case was associated with laceration of the internal mammary artery, and another with laceration of the pulmonary artery.

Other injuries encountered at operation included an ice pick wound of the aorta which had sealed spontaneously and a transthoracic laceration of the liver by way of the pericardium, which presented as an acute tamponade without any demonstrable cardiac wound. Pericardial laceration without cardiac injury occurred in 3 patients and a total of 5 cases of intramural, nonpenetrating, myocardial lacerations were encountered. In all, 8 of 92 explorations were negative when viewed from the standpoint of intraluminal cardiac injury. The average size of the cardiac laceration was of the order of 1.5–2.0 cm. when the injury was knife induced.

It is difficult to estimate the extent of endocardial laceration; in one extreme case, an area of right auricular wall measuring 2 cm. by 6 cm. was avulsed as a result of gunshot injury.

Active bleeding was found at operation in 55 cases, absent in 29, and unknown in 8 (Fig. 2). Acute bleeding in these 55 cases occurred even in the face of profound hypotension, such as that occurring with decompression into the pleural cavity. It is evident that such wounds would not seal spontaneously.

The postoperative complications encountered in this series of cardiac injuries are comparable to those seen in any large traumatic series. It must be emphasized that the moribund condition of some of the patients precludes some of the niceties of preoperative preparation one would expect with elective surgical procedures. Many of the patients had more than one postoperative complication. Cardiac

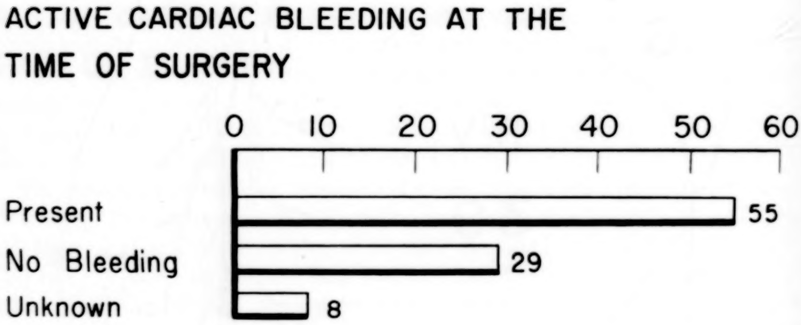

FIG. 2. Bleeding at the time of cardiorrhaphy

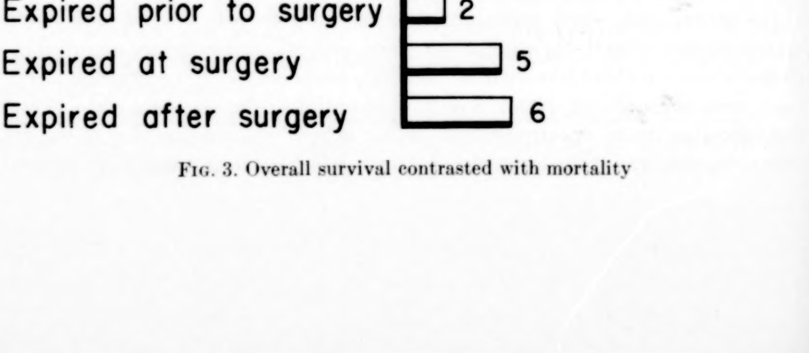

FIG. 3. Overall survival contrasted with mortality

TABLE I

Hospital Number	Age	Cardiac Arrest	Heart Wound Palpable in the Emergency Room	Expired Prior to Operation	Expired at Operation	Massive Bleeding	Comment
253206	20	+ Responded	+			+	Heart lac., closed in E.R. chest in O.R. Remained apoenic Reqd. Bennet Resp. Expired 10 hrs. post op.
222465	53	+ Unresponsive			+	+	Massive bleeding. 5000 cc blood s̄ effect asystole that was unresponsive.
185518	43				+	+	Unresponsive ventricular fibrillation.
193398	32	+ Unresponsive			+		
220127	23	+ Responded		+			
226610	47						Responded to massage. Expired 16 hrs. post. op.
200874	51				+	+	G.S.W. L. auricle & associated lacerations of lung, liver, femoral vessels: 8000 cc. blood s̄ any effect.
19334	34		+			+	Expired 4 hrs. post. op. in irreversible shock.
50-17084				+			
49-182 John Doe #11				+			
1732349	15						Observed - convulsed - operated anoxic - expired 10 hrs. post. op.
244399	31						Developed C.H.F. 1 week post. op. Expired 24 hrs. later
52-17482	76						G.S.W. of l. ventricle. Expired 10 days post. op. of massive infarct c tachycardia & B.B.B.

arrest occurred in 10 cases, of which 5 lived. One patient had two episodes of arrest, another had an arrest 16 hours postoperatively. Methods of cardiac resuscitation included massage, electroshock, and administration of Isuprel, adrenalin, calcium chloride and other agents, as clinical conditions warranted.

Specific cardiac complications included 1 case of interventricular septal defect and 1 of aortic-ventricular fistula formation. Both have been proven by subsequent cardiac catheterization, and are attributed to intraluminal injury.

Electrocardiograms were studied serially on 79 patients. The most common findings were sub-epicardial damage and pericarditis, respectively. Curiously, when electrocardiographic correlation was sought in 4 known coronary vessel lacerations, only one patient demonstrated a frank infarct pattern; another showed a possible infarct pattern, and 2 were considered to have normal patterns. Coronary vessel size precludes repair with expectation that the anastomosis will remain patent. Arteriorrhaphy was nevertheless attempted using standard techniques.

The overall survival rate of these 102 cases was 87 per cent. Ninety-two cases were treated surgically, the fatality rate being 13 per cent. Eight were treated by aspiration alone and in this group there was a mortality of 13 per cent (Fig. 3).

The fatalities are reviewed in Table I. Two expired prior to operation, 5 expired at surgery due to cardiac arrest, and 6 expired postoperatively of various complications. The injuries in these patients were produced by knives in 9, gunshot in 2, and the instrument unknown in 2 others.

Figure 4 compares and contrasts equivalent series of cardiac injuries from several centers (7, 11, 14, 15, 20).

COMPARATIVE RESULTS OF ASPIRATION WITH
SURGICAL THERAPY

Author	Year	Cases	Rx	Mortality
Blalock & Ravitch	1943	18	Aspiration	6%
Maynard, et. al.	1952	81	Surgical and Aspirational	57%
		32	Surgical	25%
Griswold & Drye	1954	82	Surgical	24%
DeBakey & Cooley	1955	57	Surgical	50%
			Aspiration	11%
Howard, et. al.	1958	39	Aspiration	13%
Jordan, et. al.	1959	8	Aspiration	13%
		92	Surgical	13%

FIG. 4. Comparison of methods of thearpy from several centers

Discussion

The management of cardiac wounds is still a subject for disagreement among surgeons. The basic surgical principle of control of hemorrhage applies strikingly to cardiac wounds. Operative treatment has been our method of choice; the rationale for employing this method is control of hemorrhage. Aspiration has been limited to a small number of patients; when bleeding did not recur, they were treated by this method alone. In those cases where repeated aspiration revealed reaccumulation of blood, exploration was performed specifically for control of hemorrhage. Justification for continuation of this combined method of treatment seems to be substantiated by our results.

The type of cardiac injury and the location of the wound are important in evaluation. Ice pick wounds respond to aspiration and rarely reform a hemopericardium. However, if the wound is located in a site other than the aorta or one of the ventricles, extensive bleeding may occur even from such a small puncture wound. Although pericardiocentesis is of great help both as a diagnostic procedure and as immediate treatment, if repeatedly performed during extended observation invaluable time can be lost and the patient's condition can deteriorate to such an extent that the operative risk is considerably increased.

The nature of the cardiac wound is also an important factor in selection of therapy. One knife wound of the heart was treated by initial aspiration and continued observation. Three days after admission, this patient developed profound shock and expired within minutes. This we believe represented the release of a clot occluding the cardiac wound. The mechanism of bleeding, clot formation, and clot retraction undoubtedly may lead to occlusion of smaller wounds, however, in larger wounds such as due to knife trauma, the clot may well be expressed during systole or when normal blood pressure is restored.

Many patients in this series did not have tamponade, but were in shock due to extensive hemorrhage into the pleural space so that operation was mandatory to control hemorrhage. Moreover, out of 84 patients in which these data were recorded, 65 per cent presented active cardiac bleeding at the time of operation in the face of profound shock, and in the surgeon's opinion this bleeding probably would not have ceased spontaneously.

Summary

1. One hundred and two cases of penetrating injuries of the heart are presented.
2. Fifty-five patients had active bleeding from the cardiac wound at time of operation.
3. Eight cases suspected of having penetrating cardiac injury revealed none at operation.
4. A surgical mortality of 13 per cent in 92 separate cases indicates that cardiorrhaphy is an acceptable method of treatment.

REFERENCES

1. Beck, C. S. Two cardiac compression triads. J.A.M.A., **104:** 714, 1935.
2. Beck, C. S. The management of wounds of the heart. S. Clin North America, **38:** 1557, (Dec) 1958.

3. Blalock, A. and Ravitch, M. M. A consideration of the nonoperative treatment of cardiac tamponade resulting from wounds of the heart. Surgery, **14:** 157, 1943.
4. Blau, M. H., Johnston, C. J. and Ravdin, I. S. Wounds of the heart. Am. J. Med. Sc., **210:** 252, 1945.
5. Block, S. Verhandlungen der Deutschen gesellschaft für chirurgie. Elfton Congress, Berlin, 1882, Pt. 1, p. 108.
6. Cappelen, A. Vulni cordis, sutur of hjertet. Norsh M.F. laegenidensk, **11:** 258, 1896. Cited by Beck, C. S.
7. Cooley, D. A., Dunn, J. R., Brockman, H. LeR. and DeBakey, M. E. Treatment of penetrating wounds of the heart, experimental and clinical observations. Surgery, **37:** 882, 1955.
8. Cooper, F. W., Jr., Stead, E. A., Jr., and Warren, J. V. The beneficial effect of intravenous infusions in acute pericardial tamponade. Am. Surg., **120:** 822, 1944.
9. Del Vecchio, S. Sutura del cuore. Reforma med. 11: 79, 1895. Cited by Ballance, C. The surgery of the heart. Lancet, 1: 1 (Jan. 3), 1: 73 (Jan. 10), **1:** 134 (Jan. 17), 1920.
10. Fischer, G. Die wunden des herzen und herzenbentels. Arch. f. Klin. Chirug. **9:** 571, 1868.
11. Griswold, R. A. and Drye, J. C. Cardiac wounds. Ann. Surg., **139:** 783, 1954.
12. Jordan, P., Jr., and Wilson, G. E., Jr. Surgical treatment of vascular trauma. S. Clin. North America., **33:** 1151, 1953.
13. Larrey, D. J. Clin. Chir., **2:** 303, 1829. Cited by Ballance, C.
14. Maynard, A. DeL., Marcelino, J. A. and Naclerio, E. A. The management of wounds of the heart. A recent series of 43 cases with comment on pericardicentesis in hemopericardium. Ann. Surg., **144:** 1018, 1956.
15. Maynard, A. DeL., Cordice, J. W. V., Jr., and Naclerio, E. A. Penetrating wounds of the heart. A report of 81 cases. Surg., Gynec., & Obst., **94:** 605, 1952.
16. Parmley, L., Mattingly, T. W. and Manion, W. Penetrating wounds of the heart and aorta. Circulation, **17:** 953, 1958.
17. Rehn, L. Ueber penetriren de herzwunden und herznaht. Arch. f. Klin. Chir., **55:** 315, 1897.
18. J. Riolanus. J. Encheiridium anatomicum at pathologicum, in quo ex naturali constitutione partium, recessus a naturale statu demonstratur; ad usum theatri anatomici adornatum. Lugd. Bat., A. Wyngaerden, 1649.
19. Roberts, J. D. The surgery of the pericardium. Ann. Anat. & Surg., 4: 247, 1881. Cited by Cox, D. M. Wounds of the heart. Arch. Surg., **17:** 482, 1928.
20. Wilkinson, A. H., Jr., Buttram, T. L., Reid, W. A. and Howard, J. M. Cardiac injuries. Ann. Surg., **147:** 347, 1958.

PENETRATING WOUNDS OF THE HEART

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Among the more spectacular injuries encountered by the surgeon are those involving the heart. Following the experimental work of Del Vecchio in 1895 (11) and a successful clinical cardiorrhaphy by Rehn in 1896 (34), the operative management of these wounds slowly became a part of the surgeon's therapeutic armamentarium. For many years cardiorrhaphy was considered the method of choice in the treatment of penetrating wounds of the heart, and a number of series employing this method were accumulated (5, 7, 13, 18, 22, 24, 27, 32). Many still consider the operative approach as the only practical means of managing these injuries (18, 24, 27, 32).

Aspiration of the pericardial sac as the primary treatment of cardiac wounds was suggested as early as 1649 by Riolanus (35) and used clinically by Larrey in 1829 (21). By 1886 a series of 425 cases managed by venesection and pericardial aspiration had been collected and reported by Fischer, but the mortality was 84 per cent (16). It was for Blalock and Ravitch in 1943 to point out the rationale of pericardicentesis with fluid and blood replacement (6) and subsequently to report a high degree of clinical success (33). This series of cases managed by pericardial aspiration at the Johns Hopkins Hospital has recently been brought up to date with excellent results (19). Elkin, a former proponent of operative therapy in cardiac wounds, found pericardicentesis helpful in the primary management of these wounds (14). The series he reported from the Grady Memorial Hospital has also been extended to the present and shows impressive results (39).

Over the past decade many surgeons have come to accept pericardicentesis as the primary therapeutic measure in the treatment of penetrating heart wounds, considering cardiac tamponade as the single most important life endangering factor in these cases (8, 15, 19, 36, 39). Cardiorrhaphy, in their hands, is reserved for those patients who fail to respond to pericardicentesis or who deteriorate following an original favorable response to pericardial aspiration. Those surgeons advocating cardiorrhaphy as the primary method of managing cardiac wounds consider hemorrhage and associated injuries as the primary causes of death. It would almost appear that various authors are seeing an entirely different type of cardiac injury, and such has been suggested (17, 18, 30).

During this same decade numerous technical advances have been made in the

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fields of anesthesiology and cardiac surgery. Since a review of 57 cases of penetrating wounds of the heart was reported from this center in 1955 (8), there has been a gradual change to a more aggressive attitude in our management of these injuries, although pericardicentesis remains the primary method of treatment. To re-evaluate our position in the management of cardiac wounds in the light of present knowledge and recent experience the following study was done.

CLINICAL MATERIAL

The Houston Police Department and the Harris County Sheriff's Office generally route all cases involving malicious or accidental trauma to Jefferson Davis Hospital, the city-county hospital for the indigent. Those cases dead on arrival are then taken to the Harris County Morgue at Jefferson Davis Hospital where a medico-legal autopsy is carried out by the Medical Examiner. Statistics from the Medical Examiner's office have been used as a basis for the number of patients with penetrating wounds of the heart dead on arrival, and figures from the emergency room records have been used to determine those cases arriving with any sign of life. This series should therefore encompass the total experience with heart wounds in Houston and Harris County.

These records reveal that 399 penetrating wounds of the heart occurred in Houston and Harris County during the nine year period of study from January 1, 1951, to January 1, 1960. Two hundred and sixty were found to be dead on arrival, an original mortality of 65.2 per cent. One hundred and thirty-nine patients (34.8 per cent), of which four were women, showed some sign of life on arrival in the emergency room. The majority were in the second and third decades of life, although their ages varied from 13 to 63 years. One hundred and twelve were Negro and 27 were white. Stab wounds produced 117, or 84.2 per cent, of the injuries, and gunshot wounds caused the other 22. Diagnosis in each case was based on a combination of clinical findings, including elevated venous pressure, lowered arterial pressure with a narrow pulse pressure, positive pericardicentesis, roentgenographic demonstration of hemo or pneumopericardium, electrocardiographic changes of pericarditis, operative findings, or demonstration of a penetrating heart wound at autopsy.

ASSOCIATED INJURIES

To determine the relative frequency and type of associated injuries, the most recent series of 82 cases was surveyed and the results tabulated (Table I). The pleural spaces were the most frequently involved with pneumo or hemothorax, unilateral or bilateral, present in 45 cases. The aorta was involved in four cases, which have been reported previously (4). The associated injuries often played a major role in the demise of the patient.

CONDITION OF PATIENTS

Fifty-three of the 139 patients had no detectable blood pressure on arrival at the hospital. An additional 47 were found to have an arterial systolic pressure of 90 mm. Hg or less when first seen. Only 29 were normotensive before the institu-

TABLE I

Associated Injuries in 82 Patients with Penetrating Wounds of the Heart

No associated injuries	25
Associated injuries	57
Pleural Cavity	45
Hemothorax	33
Pneumothorax	8
Hemopneumothorax	4
Liver	10
Diaphragm	8
Extremity	7
Abdomen	6
Aorta	4
Stomach	4
Neck	3
Small bowel	3
Colon	2
Nerve	2
Mesentery	2
Inferior vena cava	2
Spleen	2
Kidney	2
Tendon	1
Skull	1
Pancreas	1
Esophagus	1
Pulmonary artery	1
Bronchus	1

tion of resuscitative measures. Admission blood pressure determinations were not recorded on the remaining ten patients. As usually noted, delirium was present in a large number of the patients. Often there was no venous distention or elevation of venous pressure at the time of arrival, probably because of extreme hypovolemia, as these classical signs of cardiac tamponade soon appeared during the restoration of circulating blood volume. Venous pressure measurements were made in approximately half the cases and were almost uniformly elevated above 200 mm. H_2O, many times reaching 300–400 mm. H_2O or more. In those patients in whom venous pressure measurements were not made, distended veins in the presence of shock were frequently described at some time during the course of therapy. Heart sounds were often described as distant or absent. Pulsus paradoxus was noted in approximately one-third of the cases.

PLAN OF TREATMENT

Patients admitted to the emergency room with wounds of the precordium, chest, or upper abdomen are examined promptly for signs of cardiac tamponade. Simultaneously, a route for the administration of intravenous fluids is obtained. If shock is present a large bore polyethylene tube is inserted into the greater saphenous vein; however, a vein of an upper extremity is used when the wound is below the diaphragm, because of the possibility of inferior vena caval injury. Colloid solution, vasopressors, and uncrossmatched, type O-negative, whole blood are given as indicated. Sucking wounds are closed rapidly with Vaseline (R) gauze pressure dressings or temporary suture. Equipment for the rapid institution of intercostal thoracostomy tube drainage is kept in readiness in the emergency room at all times and is used if a significant pneumo- or hemothorax is present. When the patient's condition permits, the chest is examined roentgenographically and an electrocardiogram is made. Frequently these procedures are carried out prior to pericardicentesis, but only when the diagnosis of tamponade is in question and the patient's condition permits. Blood loss into the pericardium and into the pleural space is replaced as rapidly as possible. Specific type, crossmatched, whole blood is used as soon as available.

Those patients whose condition is considered stable without pericardicentesis or who stabilize after aspiration of the pericardial sac are moved to the recovery room for intensive observation and subsequently to the ward. Patients who fail to respond to pericardicentesis or whose condition again deteriorates are moved to the operating room, the nursing and anesthesiology personnel having been alerted at the time of the patient's admission to the emergency room. If the patient's condition again improves and remains stable after a subsequent aspiration, he is moved to the recovery room. If not, thoracotomy and cardiorrhaphy are carried out as rapidly as possible.

Prolonged delay in the progression to cardiorrhaphy has not been noted as a consequence of this plan of management. Freuqently intravenous fluids have been started, sucking wounds temporarily closed, a thoracostomy tube inserted, pericardicentesis performed, the patient moved to the operating room, and cardiorrhaphy begun in a period of less than fifteen minutes. In the more desperate cases the patient has been taken directly to the operating room on the ambulance stretcher. A major thoracotomy set is kept in the emergency room at all times, and in extreme cases cardiorrhaphy has been carried out there, frequently with survival of the patient.

RESULTS

Of the 139 patients who arrived alive at the emergency room, 35 died, or 25.2 per cent. This figure includes ten patients who expired before any treatment could be instituted and nine patients in whom cardiac action ceased before the onset of therapy but in whom cardiac massage was attempted. Were these 19 deaths to be excluded, the corrected mortality would be 14.4 per cent. However, if all deaths are included, regardless of whether the patient reached the hospital alive or whether death occurred before the institution of therapy, there was a gross mortality of 71.4 per cent for heart wounds sustained in Houston and Harris County. Statistics such as these are helpful in evaluating methods of managing these patients and make speculation unnecessary as to the rapidity of the ambulance service and the relative severity of the injuries treated in various hospitals and medical centers.

The method of treatment employed and the outcome are outlined in Table II.

TABLE II

Results of Treatment

	Jan. 1951 to Oct. 1954		Oct. 1954 to Jan. 1960		Jan. 1951 to Jan. 1960	
No treatment		15		22		37
Expired	8		2		10	
Recovered	7		20		27	
Thoracotomy for Resuscitation		1		11		12
Expired	1		8		9	
Recovered	0		3		3	
Pericardicentesis		34		44		78
Single						
Expired	3		0		3	
Recovered	14		18		32	
Multiple						
Expired	0		0		0	
Recovered	11		9		20	
Thoracotomy						
Resuscitation						
Expired	1		4		5	
Recovered	0		3		3	
Cardiorrhaphy						
Expired	2		2		4	
Recovered	3		8		11	
Primary Thoracotomy		7		5		12
Expired	3		1		4	
Recovered	4		4		8	
Total		57		82		139

These are broken down into the previously reported group of 57 patients seen between January, 1951, and October, 1954 (8), the most recent series of 82 patients seen between November, 1954, and January 1, 1960, and the combined results of the entire series of 139 patients. Thirty-seven patients received no treatment, with a mortality of 27 per cent. The mortality among this group was quite different for the two periods, however, and during the latter period reflects a more aggressive attitude on the part of the resident staff, both in the diagnosis of minor cardiac injuries not requiring treatment and in the prompt diagnosis and treatment of patients who would have otherwise expired without treatment. Only two patients died in the emergency room without immediate thoracotomy and attempted resuscitation during this period. In twelve patients whose hearts stopped before therapy could be instituted, immediate cardiac massage and cardiorrhaphy saved three.

Seventy-eight patients were treated primarily by pericardicentesis, with a mortality of 5.5 per cent in those requiring aspiration alone. It should be noted, however, that there were no deaths from aspiration alone during the latter period, which again reflects a more aggressive attitude. Any patient having cessation of cardiac action immediately underwent thoracotomy and cardiac massage. This was carried out whether in the emergency room, operating room, recovery room, or on the ward. It is significant in this regard, that the salvage rate in those patients undergoing thoracotomy after failure or pericardicentesis is actually better during the latter period than during the earlier period, in which three patients expired without thoracotomy after failure of aspiration treatment.

A comparison of those patients undergoing thoracotomy after failure of pericardicentesis reveals a mortality of 26.7 per cent if cardiorrhaphy is undertaken before cardiac arrest ensues. However, if cardiac arrest occurs, the mortality rises to 62.5 per cent, further supporting the necessity of an aggressive approach should the response to pericardicentesis not be immediate and lasting. In those patients whose condition was considered to be of such severity as to necessitate thoracotomy and cardiorrhaphy without prior aspiration, the overall mortality was 33 per cent but only 20 per cent in the more recent series. As can be seen from these figures, a direct comparison of the results of aspiration and of thoracotomy in this series would be entirely misleading, as the majority of deaths, by this plan of treatment, necessarily fall into the operative group.

DISCUSSION

The operative management of penetrating wounds of the heart was for many years the method of choice. Proponents of this classical approach have cited many advantages of such a method. One of the most frequently quoted advantages of the operative approach has been the ability thereby to manage satisfactorily various concomitant injuries. Another is the control of major hemorrhage. Many of the so-called advantages of immediate thoracotomy are in actuality the prevention of possible complications of pericardicentesis. Damage to the heart by the aspirating needle is certainly a theoretical possibility (18), but was not noted in this series. We have not been impressed with the frequency of major uncontrollable hemorrhage, although this does occasionally occur and demands immediate thoracotomy. Tamponade can certainly be relieved by widely opening the pericardial sac, but in our hands satisfactory relief of tamponade has been possible by pericardicentesis in the majority of cases. Although clotted tamponade, which prevents satisfactory pericardicentesis, has occurred in this series, it has not been seen with the frequency reported by others (18, 24, 27, 32). If tamponade is not rapidly relieved by pericardicentesis, thoracotomy is still available if too much time is not lost in futile attempts at aspiration. Primary aspiration treatment must not be continued to the exclusion of thoracotomy should it be indicated.

Delayed hemorrhage from heart wounds certainly does occur (10, 18, 20, 32), but has not been found to be a practical consideration in the management of these cases. When it does occur, it is only with extreme rarity and it was not seen in the present series.

Constrictive pericarditis, following cardiac trauma, both penetrating and nonpenetrating, has been well documented (1, 2, 3, 12, 25, 28, 31, 37). Although this complication may occur following the incomplete evacuation of a hemopericardium, it has not played a prominent part in the management of the present group of cases. No case of true organized constrictive pericarditis was seen. Five of the

139 patients developed chronic pericardial effusions requiring repeated aspirations. Three have come to partial pericardectomy, one may require such a procedure in the future, and the other remains asymptomatic, three years after his last pericardicentesis. All 139 patients have not been followed closely for this complication, but for the most part these have been indigent patients who return to Jefferson Davis Hospital with their medical complaints. Most have been seen on occasion in the emergency room or in the clinics for various unrelated complaints, subsequent to the time of their heart wound.

The development of a ventricular aneurysm is another sequela of penetrating wounds of the heart. Lyons has reported the successful management of such a case (23). This complication was not seen in the present series. Ventricular aneurysm cannot be considered as an aftermath of only the aspiration method of management, for such a case has been recently referred to one of the Baylor University College of Medicine affiliated hospitals following primary cardiorrhaphy elsewhere. The present series does include several unusual injuries, but all are unrelated to the primary method of management. Three patients were found to have aorto-right ventricular fistulas as a result of stab wounds. Two have been reported previously (29). All three were managed primarily by pericardicentesis, and have subsequently undergone successful repair of the defect utilizing total cardiopulmonary bypass. Two patients treated by aspiration have persistent heart murmurs suggestive of small ventricular septal defects. Right heart catheterization in one revealed normal pressures with no evidence of left-to-right shunt. The other patient remains asymptomatic and further studies have not yet been carried out.

Inherent in the operative management of heart wounds are certain practical disadvantages. Such heroic surgical maneuvers require skilled personnel to prepare the operating room, give the anesthetic, and perform the operation. Such personnel are not always immediately available. Moreover, these injuries tend to appear on the busiest night in the emergency room, and occasionally two patients with the same type of wound are admitted simultaneously. Furthermore, the general condition of these patients can make them extremely bad operative risks. Their intake of alcohol has usually been to excess, a factor which has been shown experimentally to decrease tolerance to cardiac tamponade (8). Positive pressure anesthesia is likewise known to reduce the tolerance to tamponade, and these effects are further enhanced by the use of pentobarbital and ether as anesthetic agents in the presence of tamponade (8). It would seem that thoracotomy, if required in these patients, should be delayed until their general condition be improved, if such delay is not associated with further risk.

Thus, fortunately, not only is primary aspiration of penetrating wounds of the heart more convenient for the hospital personnel, but more important, it appears to offer the patient the best possible chance for survival in most instances. During the evaluation of the patient in the emergency room many pathophysiologic processes can be corrected or improved. A diminished circulating blood volume can be returned toward normal, and the temporary beneficial effects of intravenous fluids in pericardial tamponade may be utilized (9). Sucking wounds are closed and the lungs expanded, providing a more physiologic state for the induction of anesthesia, should this become necessary. Pericardicentesis is carried out, and even in those cases in which subsequent cardiorrhaphy is required, the aspiration of only a small amount of blood from the pericardial sac may resuscitate even the most desperate case and maintain life until cardiorrhaphy can be performed. The physiology of cardiac tamponade is such that at a certain critical point, small amounts of blood introduced into or removed from the pericardial sac may produce a marked effect on the circulatory status of the patient (8, 26, 38). With the general condition of the patient thus improved, cardiorrhaphy, if necessary, can then be more safely performed. Undue time should not be lost, however, by refusal to accept the inadequacy of pericardicentesis in a certain number of cases.

SUMMARY

Neither pericardicentesis nor cardiorrhaphy can be accepted as the only method of treating penetrating wounds of the heart. Each case must be individualized and managed as conditions dictate. Since January 1, 1951, it has been the policy at Jefferson Davis Hospital, a city-county general hospital for the indigent, to begin therapy in these cases with temporary local care of wounds, intravenous fluids, vasopressors as indicated, blood replacement, pulmonary re-expansion when indicated, and aspiration of cardiac tamponade. If the results of such therapy are not immediate and lasting, thoracotomy is then employed without further delay, but with less risk as a result of the patient's improved general condition.

During the nine-year period of study 399 individuals sustained penetrating wounds of the heart in Houston and Harris County, of which 139 showed some sign of life on arrival at the hospital. The overall mortality in that group of patients reaching the hospital alive was 25.2 per cent; however, if those patients who expired before any form of therapy could be instituted are excluded, the mortality was only 14.4 per cent. Thirty-seven received no treatment, and 27 per cent of these died. Cardiac massage and cardiorrhaphy saved three of twelve patients in whom cardiac arrest ensued before any form of treatment could be started. Seventy-eight were treated primarily by pericardicentesis with a mortality of 5.5 per cent in those requiring only aspiration. Among 23 patients who did not respond to pericardicentesis, the mortality was only 26.7 per cent if cardiorrhaphy was carried out immediately, but rose to 62.5 per cent if cardiac action was allowed to stop before thoracotomy was employed. Twelve of the more desperate cases were treated primarily by cardiorrhaphy, with 33 per cent mortality.

Re-evaluation of this method of management with the passage of time and the accumulation of further experience, continues to support its rationale and efficacy. Over the years the trend has been toward earlier thoracotomy in those patients who do not respond to aspiration, but pericardicentesis remains our primary approach to penetrating wounds of the heart.

REFERENCES

1. Ada, A. E. W., Jones, O. R. and Sheeran, A. D. Partial pericardectomy in a case of hemopericardium due to nonpenetrating trauma. J. Thoracic Surg., **20:** 105–108, 1950.

2. Avery, E. E.: Discussion of Holman, E. The recognition and correction of constrictive pericarditis. J. Thoracic Surg., **18:** 643–651, 1949.
3. Baker, P. S. and Johnston, F. D. Chronic pericarditis with effusion. Circulation, **2:** 134–138, 1950.
4. Beall, A. C., Jr. Penetrating wounds of the aorta. Am. J. Surg., **99:** 770–774, 1960.
5. Bigger, I. A. Heart wounds. J. Thoracic Surg., **8:** 239–251, 1939.
6. Blalock, A., and Ravitch, M. A consideration of the nonoperative treatment of cardiac tamponade resulting from wounds of the heart. Surgery, **14:** 157-162, 1943.
7. Blau, M. H. Wounds of the heart. Am. J. Med. Sc. **210:** 252–262, 1945.
8. Cooley, D. A., Dunn, J. R., Brockman, H. L. and DeBakey, M. E. Treatment of penetrating wounds of the heart: Experimental and clinical observations. Surgery, **37:** 882–889, 1955.
9. Cooper, F. W., Jr., Stead, E. A., Jr., and Warren, J. V. The beneficial effect of intravenous infusions in acute pericardial tamponade. Ann. Surg. **120:** 822–825, 1944.
10. Cosman, B., Byerly, W. G. and Wichern, W. A. Penetrating wounds of the heart with delayed recurrent hemothorax: Case report. Ann. Surg., **147:** 87–92, 1958.
11. Del Vecchio. Sutura del cuore. Riforma med. 79–80, 1895. Cited by Ballance, C. The surgery of the heart. Lancet, **1:** 1–5, 73–79, 134–139, 1920.
12. Ehrenhaft, J. L. and Taber, R. E. Hemopericardium and constrictive pericarditis. J. Thoracic Surg. **24:** 355–366, 1952.
13. Elkin, D. C. Wounds of the heart. Ann. Surg., **120:** 817–821, 1944.
14. Elkin, D. C. and Campbell, R. E. Cardiac tamponade; treatment by aspiration. Ann. Surg., **133:** 623–628, 1951.
15. Farringer, J. L. and Carr, D. Cardiac tamponade. Ann. Surg., **141:** 437–442, 1955.
16. Fischer, F. Lang. Arch. **9:** 608, 1886. Cited by Ballane (see ref. 11).
17. Griswold, R. A. Personal communication.
18. Griswold, R. A. and Drye, J. C. Cardiac wounds. Ann. Surg., **139:** 783–785, 1954.
19. Isaacs, J. P. Sixty penetrating wounds of the heart. Clinical and experimental observations. Surgery **45:** 696–708, 1959.
20. Johnston, C. G.: Discussion of Drye, J. C., Coe, W. S. and Stamer, J. P. Heart wounds—a long term follow-up of twenty cases. Am. J. Surg., **91:** 597–599, 1956.
21. Larrey, D. J. Clin. chir. **2:** 302, 1829. Cited by Ballance (see ref. 11).
22. Linder, H. and Hodo, H. Stab wounds of the heart and pericardium. South. Med. J. **37:** 261–266, 1944.
23. Lyons, C. and Perkins, R. Resection of a left ventricular aneurysm secondary to cardiac stab wound. Ann. Surg., **147:** 256–260, 1958.
24. Lyons, C. and Perkins, R. Cardiac stab wounds. Am. Surgeon, **23:** 507–519, 1957.
25. Maguire, C. H. Discussion of Elkin, D. C. and Campbell, R. E. Cardiac tamponade: Treatment by aspiration. Ann. Surg., **133:** 623–628, 1951.
26. Martin, J. W. and Schenk, W. G. Pericardial tamponade. Newer dynamic concepts. Am. J. Surg., **99:** 782–787, 1960.
27. Maynard, A. DeL., Avecilla, M. J. and Naclerio, E. A. The management of wounds of the heart. A recent series of 43 cases with comment on pericardicentesis in hemopericardium. Ann. Surg., **144:** 1018–1022, 1956.
28. McKusick, V. A., Kay, J. H. and Isaacs, J. P. Constrictive pericarditis following traumatic hemopericardium. Ann. Surg., **142:** 97-103, 1955.
29. Morris, G. C., Jr., Foster, R. P., Dunn, J. R. and Cooley, D. A. Traumatic aorticoventricular fistula: Report of two cases successfully repaired. Am. Surgeon, **24:** 883–888, 1958.
30. Noer, R. J. Discussion of Ransdell, H. T. and Glass, H., Jr. Gunshot wounds of the heart. A review of twenty cases. Am. J. Surg., **99:** 788–797, 1960.
31. Overholt, R. H., Burwell, C. S., Woodbury, J. W. and Walker, J. H. Constrictive pericarditis and constrictive pleuritis treated by pericardectomy and pulmonary decortication. Report of a case. J. Thoracic Surg., **23:** 1–11, 1952.

32. Ransdell, H. T., and Glass, H., Jr.: Gunshot wounds of the heart. A review of twenty cases. Am. J. Surg. **99:** 788–797, 1960.

33. Ravitch, M. M. and Blalock, A. Aspiration of blood from pericardium in treatment of acute cardiac tamponade after injury. Further experience, with report of cases. Arch. Surg., **58:** 463–477, 1949.

34. Rehn, L. Ueber penetrirende herzwuden und herznaht. Arch. Klin. Chir., **55:** 315–329, 1897.

35. Riolanus. Lang. Arch. **9:** 608, 1886. Cited by Ballance (see ref. 11).

36. Royster, H. P. and Bosher, L. H. Aspiration treatment of cardiac tamponade. Arch. Surg., **77:** 117–122, 1958.

37. Skinner, H. L. and Farr, K. F. Decortication of the heart. Report of a case. J.A.M.A., **152:** 234–235, 1953.

38. Williams, C. and Soutter, L. Pericardial tamponade. Arch. Int. Med., **94:** 571–584, 1954.

39. Wilkinson, A. H., Buttram, T. L., Reid, W. A., and Howard, J. M. Cardiac injuries. An evaluation of the immediate and long range results of treatment. Ann. Surg., **147:** 347–352, 1958.

DISCUSSION

Dr. Hugh E. Stephenson, Jr. (Columbia, Missouri): I think the problem of penetrating wounds of the heart has been beautifully presented here this morning from some of the stab wound centers of the country. I must say that the incidents of chest stabbing in Missouri have been, I think, very seldom seen, at least by us, in recent years, since the ice pick is a little hard to find and we just haven't had a lot of experience, but we have been interested in following this somewhat of a controversy in the literature over the past decade or so, since Blalock in 1942 more or less reversed the trend toward early thoracotomy, and in 1942 Drs. Grimm, Eggers and Churchill in the United States Army Bulletin more or less adopted the same recommendation; that is, aspiration of blood from the pericardial sac first. If no improvement resulted, this should be repeated, and then if the symptoms progressed, thoracotomy should be performed.

I do think that Dr. Beall has made a very excellent case for the thoracotomy approach. Certainly we have felt that the site and extent of injury can be more easily determined if thoracotomy is done early.

I think we should distinguish between causes of death. Some of these patients died from exsanguination and some died, perhaps, from tamponade, a difference in mechanism. He didn't mention some of the associated injuries that perhaps he might have if he had had time.

I wonder if he had any instances of heart block, internal mammary artery transections along with this; septal defects, or lacerations of the coronary artery, or perhaps tearing of the aortic valve.

The infrequency of these—at least we feel that it is very often impossible for us to aspirate blood from the pericardial sac, just as it is in the acutely bleeding G.I. hemorrhage. We have operated on a number of G.I. bleeders, such as I am sure all of you have, where the tube has been in the stomach and the whole stomach is filled with a cast of clotted blood.

I would like to emphasize, and I think Dr. Beall perhaps has underemphasized, the hazards of aspiration. We have been familiar with several instances where the coronary arteries have been lacerated by the aspiration technique. Infective pericarditis I do think is relatively rare, as was pointed out, although Ehrenhoff has seen several cases and reported on them previously.

I do think, though, that nature as a rule selects most of these cases before they arrive at the hospital, but once they arrive at the hospital, with better anesthesia, blood volume determinations more easily available, more attention to the airways, more effective methods of monitoring the heart action, our understanding of cardiac metabolism certainly has been increased. We have been using ATP, Adenosine triphosphate in glucose in resuscitation of some of the hearts that have been electively arrested and found that very valuable.

I think the use of the sternal splitting incision has aided us a great deal. New ways of closing heart lacerations have been certainly well disseminated; the use of the patch, when necessary, and use of the pacemaker for conductive disturbances, all, I think, have allowed us to reach a new era in the management of the penetrating injury of the heart, and perhaps, as Dr. Beall has pointed out so ably, we can go on from this phase into perhaps an era of lower mortality even than what has been suggested by the two groups from Detroit and Houston.

Dr. James C. Drye (Louisville, Kentucky): I suppose the position of Louisville has been well known. We still operate on them.

(Slide) This is a picture, not of a resident with an ice pick taped on him; it is an actual case. I have the ice pick on my desk.

Our hospital, as our residents say, is located in the middle of the combat zone. One of the strong points there is the Sweetheart Bar. They seem to drink fighting whiskey there, rather than courting whiskey.

We have an extremely efficient police department, which evacuates our casualties very rapidly to the hospital. On admission they are taken immediately to the operating room, not necessarily for operation—and this includes all major injuries—but for study, observation, and for resuscitation. We feel that there, with the nurses, our equipment, our anesthetists and so on, that we can do a better job than we can in the emergency room.

Our statistics, like those presented, count everybody that comes in the front door that was seen to be alive by anybody, whether it was a nurse, medical student, or anyone else. All operations are counted if an incision was made. I am sure that some of our patients on whom we operated were dead before the operation was started.

(Slide) This is our experience over the years. As you can see, our operability has risen; our total mortality has gone down and our operative mortality has been about the same. In the last year, as you can see, we have operated on 94 per cent of our patients, a total mortality of 26 per cent, which compares with 25.1 per cent in the paper presented, and our operative mortality is 22 per cent.

(Slide) This is what happened to the non-operative cases. This is not exactly a fair slide. These are not patients treated by aspiration. As you can see, 18 of them died between the emergency room and the operating room. There were two missed diagnoses, one on medicine and one that I made personally as a resident; one that refused operation. Of the 27 non-operated, six lived, five had aspiration, and one refused any treatment.

(Slide) This slide summarizes our position somewhat, and if you look at the 1906 edition of Keene's "Surgery," in the chapter written by the great giant of American Surgery, Dr. Rudolph Matas, you can pick this out of that chapter. I think these points still hold today.

Dr. Beall has made an excellent point in collecting all wounds of the heart, whether they arrived dead or alive. We are not able to do this in our community. On the other hand we have now followed a number of our patients, those that we could catch, for a number of years. We have a study on 20 of 60; it is all we could find of the 60 who had had wounds for over ten years, and we have found no evidence of heart disease due to the trauma.

Dr. Beall says he has seen no constrictive pericarditis, but I wonder how many of his patients he has been able to follow. These patients are extremely difficult to get back; they don't like police looking for them, they don't like social workers looking for them, and so on.

I would disagree somewhat with Dr. Beall in that the aspiration management is the best chance. I think our figures compare with his. We do use aspiration at times in preparation for the cardiotomy procedure.

Dr. Vollrad J. von Berg (Detroit, Michigan): Beck's triad was initially defined as a large, quiet heart with an elevated venous pressure and shock.

In our experience, involuntary defecation on admission was something that was very commonly found in association with patients who were very nearly totally irrational in terms of being apprehensive and the like.

I, too, wish to thank the discussers for their kind remarks. For Dr. Stephenson I would like to add that we have had in this series four cases of coronary artery or coronary vein laceration with primary repair, fully realizing that this is a small vessel and not anticipating its remaining open. Of these four cases, two had normal postoperative electrocardiograms, one had a possible infarct pattern, and one did have an infarct pattern.

Dr. Arthur C. Beall, Jr. (Houston, Texas): I certainly wish to thank the discussers for their comments.

In answer to Dr. Stephenson, we have had several unusual injuries, including three cases of aorto-right ventricular fistulas successfully repaired, utilizing total cardio-pulmonary bypass, and probably two cases of interventricular septal defects. One has had a normal right heart catheterization. The other has not been studied as yet because he is asymptomatic.

I am sorry that time did not allow us to present these. They will be covered in the manuscript.

Although there is a possibility of damage to the heart from aspiration, as has been mentioned, it was not seen in this series. Also, complete aspiration, not possible in some cases, perhaps is not necessary. As pointed out at this meeting last year, and in many previous studies, removal of small amounts of blood from the pericardial sac may make a considerable difference in the patient's clinical condition.

In answer to Dr. Drye, I do not have a complete followup on all of these cases. However, these patients are indigent patients and the majority have been seen at one time or another in the emergency room or in various clinics at Jefferson Davis Hospital subsequent to their cardiac injuries for various unrelated complaints. Exact followups cannot be given, as Dr. Drye mentioned, because these patients are difficult to find unless they want to find you.

I would like to re-emphasize one point. We do not use pericardicentesis to the exclusion of cardiorrhaphy. We begin by aspiration, preparing these patients for cardiorrhaphy if it is required. If the patient's condition improves and stabilizes we see no need to carry through with an operation. If not, we have continued making preparations for operation and we carry out cardiorrhaphy immediately.

THE JOURNAL AND JOINT ACTION*

JAMES K. STACK, M.D.

On such annual occasions in the past, your Presidents have spoken to you of many things. Some have given a professional, or scientific paper; others have reminisced, and still others have pleased you with accounts of far-away travels or local avocations. It seems to me fitting that on at least some of these occasions we should devote ourselves to the practical problems and affairs of our Association. The Presidency of an organization of this kind is unusual in that we meet in this relationship but once a year, and, in the interval between these meetings, your dealings are, for the most part, with your Secretary. Therefore, this little talk becomes, of necessity, both an inaugural and a valedictory; it's HELLO and THANK YOU, and GOOD-BYE and GOD BLESS YOU, almost in the same breath.

But, before saying good-bye, let us review some of the practical problems alluded to above. We must start this way if we are to play our role in the two projects which will occupy this group for the remainder of the professional lifetime of most of us here.

Article II of our Constitution, entitled "Object", reads as follows:

"The object of this Association shall be the cultivation and improvement of the science and the art of the surgery of trauma and allied sciences, the elevation of the medical profession and the consideration of such other matters as may properly come within its sphere." Your Board of Managers has decided that "coming properly within its sphere" are the establishment of a Journal of Trauma to be the official organ of this association, and participation with the National Safety Council and the American College of Surgeons in a Joint Action Program. They feel that "coming within its sphere" is the prevention of trauma. They feel that the art and science of prevention is as much in our sphere as the care of victims. You have concurred in this decision. This means that we are no longer a tight little socioprofessional band whose sole function is this annual meeting—highly vocational in nature.

Here we may draw an analogy. If one were in the process of critically analyzing a medical school, for instance, a fair and broad preliminary question would be: Is this school a vocational one, or is it a truly graduate institution? Both types are concerned with the pursuit of knowledge, and maybe even the pursuit of excellence, but there is a basic difference. If we, then, were to turn to an analysis of professional associations, we may fairly ask: Is this a trade association whose members have the vocational-school concept, or is it a group with an attitude of professional responsibility inculcated in a truly graduate institution environment? What is the essential difference between the vocational school and the graduate school and the trade association and our own? It is a social consciousness, and this may be defined as an awareness of responsibility to society. The impact of this concept called social consciousness has been felt by us all. It is the basis of high taxes, mutual-security pacts, human rights and legislation, farm parity and the other implements for the so-called common good, including the desire for a safe place in which to live, travel and work. Professor Millis has expressed it in terms of a striking and disturbing quest of all people of all nations for security. He says that the human dilemma of our time is the desire for security and the rejection of the responsibility that must go with it. No one can deny that by the very nature of this meeting we, as individuals, derive a certain security from it. We leave here better informed on many topics, and with the feeling that we know what is going on in this field in other parts of the country, if not the world. We feel more secure in the decisions we will reach later, and in the acts we will carry out because of what we have heard and seen here. By our action, in agreeing to participate in the Joint Action Program, we have not rejected responsibility.

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* Presidential Address, presented before the Twentieth Annual Session of The American Association for the Surgery of Trauma, Coronado, California, October 5–7, 1960.

Now, why must we do this? By what right do we do it?

You and I have individual competence attested to by diplomas, certificates, and the like, or, perhaps, we wouldn't be here. Certainly, to carry out the program to which we are committed requires competence, but of another kind, namely, group competence. Now, no group or agency—government or private—has attested to our group competence to accomplish these ends. Then, what is our reason for being? By what means are we permitted to join the National Safety Council and the American College of Surgeons in these efforts? It goes much deeper than the historic fact that several men who were to become our founding members "found ourselves at a luncheon table at the meeting of the Western Surgical Association in Indianapolis on a cold November day in 1937." We exist and are permitted to carry out our ambitious plans, because, by tradition, society in this country recognizes voluntary associations, and because group competence, not individual, permits the assumption of responsibility. You and I, as surgeons, have been educated, examined and given certain legal authority to do certain things; but you and I, as members of this voluntary association have no such legal guarantee. Let me quote from Professor Millis: "The voluntary association . . . if it gain authority, does so because society voluntarily elects to accept that authority. This is authority by voluntary consent, and that which is voluntarily given can be voluntarily withdrawn. The authority of a voluntary association, so necessary for the discharge of its responsibility, is a very fragile thing. The authority must be won and retained by continuous leadership so skillfully and effectively given that society cannot do without it." thus, we have three key words—competence, authority, responsibility. Group competence, authority by voluntary consent and responsibility that is continuous.

If the concept you hold of this Association is based on an annual meeting, the exchange of professional views, the acquisition of as many facts as possible to further our individual competence as surgeons, then we must waive our claim to group competence. We, then, have no group responsibility to society, and we must, therefore, relinquish our authority. We would then, indeed, be a kind of a trade association which is the product of vocational-school thinking. By our actions, we have rejected that.

We, alone, will be responsible for the material and the conduct of the Journal of Trauma. The name of Dr. Charles G. Johnston will appear as Founding Editor. Dr. Rudolf J. Noer of the University of Louisville will be Editor and will guide the Journal with the help of an Editorial Board he has chosen. Now, let me tell you of our partners in the Joint Action Program. The American College of Surgeons was granted a Certificate of Incorporation by the State of Illinois on November 25, 1912, although we usually think of it as being founded in 1913. This attests to the group competence of that college. The articles of incorporation were amended on November 3, 1955, and I quote from paragraph 4: "... by formulating standards and methods for the improvement of all adverse condititions surrounding the sick and injured wherever found." "... To accomplish these aims, this corporation will enlist the cooperation of other agencies or institutions already established or which may hereafter be established." It is clear from this that they, in asking us to join them, believe in our group competence.

The National Safety Council, operated as a voluntary association, unincorporated from its founding in 1913 to 1930 when its group competence was recognized by incorporation under the laws of Illinois. Then, in August of 1953, it was signally honored as President Eisenhower signed Public Law No. 259 of the 83rd Congress, creating the National Safety Council as a body corporate under federal law. This was in recognition of the ability of this Council to act as a central and guiding force in the safety movement throughout the United States. I quote from this law, Section 3, Paragraph 6, in part: "... to cooperate with, enlist and develop the cooperation of and between all persons, corporations and other organizations and agencies, both public and private, engaged or interested in, or in any manner connected with any or all of the foregoing purposes, namely, the promotion of the public safety." It is clear from this that they feel we have a competence to help in this great effort.

But you may ask—how? As an individual, the surgeon's contribution to accident-prevention consists, most likely, of suggesting little changes in the mechanics of living. You may tell a family to take up those throw rugs in the parlor so Grandma won't trip and fall. You may suggest that they move the window seat or radiator so father won't hurt his back when he leans over with his knees straight to open a window. You may tell them that a guard should be on that open gas heater so Sally won't be burned again. But we, as a group, may be able to do more than that. We do have a first-hand knowledge of the immediate and final results of accidents, and, because of our experiences in the emergency rooms, wards and in practice in general, we should be in a position to contribute more to accident-prevention. We certainly have impressions even if we do not always have statistics. We may have knowledge by having things told to us through privileged communication that would not appear in an accident report, and these might be acted upon in an indirect way that would be helpful and still not be a breach of professional confidence. The accident victim may not admit to an investigator that he has had trouble recently adjusting his insulin dosage. Another victim may have had some strange feelings and slight seizures that made him wonder if he was going to be like his uncle who used to have fits. The wife may not repeat to the safety man from the plant that John drinks heavily over the week end and that she hates to see him leave home on Monday morning so shaky and depressed. Besides, she wanted him to give up the job of a structural steel-worker a long time ago. Thus, by knowing the background, and seeing the effects, may we not throw more light on the cause?

For instance, do you appreciate the fact that fatal falls were second only to motor vehicle accidents in 1959? They accounted for 18,248 deaths out of a total of 91,000. These deaths were from falls from one level to another, or on the same level, and have nothing to do with falls from railway, highway, waterway or air transport vehicles, or those falls occurring in cataclysms. In other words, the common, little, lousy, seemingly-senseless falls that you and I are dealing with every day. A few years ago, the National Safety Council tried to conduct a major campaign against falls. It failed dismally because they just didn't know enough about the human factors involved. The Council feels that doctors could be the prime source of such basic information. If you look through this 1960 edition of "Accident Facts", published by the Council, you will share the frustrations of those who compile it because of their lack of this truly basic knowledge.

Now, I hope that some of the things I have said were not known to all of you, and I am sorry to have bored those of you who also have given this much thought in the past. Surely you will all agree that in a varied attack on the factors—tangible and intangible—that kill and cripple so many Americans each year there is a place for the particular outlook and group competence of our Association. In 1958, as a representative of this Association, I addressed a section of the National Safety Council on the subject—"The Role of National Surgical Organizations in Public Safety". I concluded by thanking them for letting me tell our side of the story, and said, "We hope that this is just the beginning of a long and fruitful partnership."

A review of our activities in the Joint Action Program suggests that we have furnished but little propellant to get this thing off the ground. Let us not be accused of going along for the ride. If you have had the feeling of being gently chided in the past few minutes, I would be less than candid if I admitted to any other intention. Let me remind you again that we are committed to the Journal and to Joint Action. We possess, as of now, only that fragile thing—authority by the voluntary consent of society. Let us retain it.

EDITORIAL

The Journal of Trauma exists for but one purpose: improvement in the management of trauma. In this second issue it seems appropriate to review its background and outline plans for its future.

The American Association for the Surgery of Trauma decided to sponsor this publication only after deliberate and thorough consideration. Dr. Johnston and Dr. Ravdin in the first issue, and Dr. Stack in his Presidential Address, reviewed some of the factors which entered into that decision. Several reasons seemed to favor the establishment of a new journal: 1) Papers on trauma would be its major interest; they would not be "put off" or relegated to a place of secondary importance. 2) Its very existence should stimulate more and better original work in this field. 3) Assembly in one place of papers relating to the various manifestations of injury should broaden the attitudes and understanding of all those concerned with the ever increasing problems of trauma, whatever their areas of special interest; it might even provide a partial antidote for the "committee of specialists" so often encountered in the care of the patient with multiple injuries. In short, it might well provide a potent influence toward elevating the standards of care in this growing and all important field.

Dr. Charles Johnston, a former president of the association, was one of the chief proponents of the new journal. His long devotion to the study of trauma, his many contacts with those interested in its problems, both medical men and those in allied fields, and his demonstrated leadership in the association made him the logical—in fact inevitable—choice of the Board of Managers as Editor. Prior to his departure for Japan in March of 1960 he assembled an outstanding group of editorial consultants, wrote the first editorial and completed plans for publication of the first issue in January 1961.

A staggering blow was dealt the new journal by Dr. Johnston's untimely death from coronary occlusion two days after his return to this country. In this emergency the publishers were helpful in extending the deadline for material for the first issue beyond the forthcoming meeting of the American Association for the Surgery of Trauma. The program committee and officers of the association generously made available free advance choice of all papers selected for presentation, and many authors went to considerable trouble to prepare their final manuscripts well before the meeting date. The excellence of the editorial board assembled by the Founding Editor was apparent in the promptness and efficiency with which its members carried out their duties to make possible prompt assembly of appropriate material for the first issue, which appeared only slightly later than the originally scheduled date.

Many have inquired as to what sort of material will be published. The subject matter of the first two issues should provide at least a partial answer to that question. All papers will relate in one way or another to the field of trauma, broadly interpreted. Every effort will be made to maintain appropriate balance between the various anatomic fields of interest as well as between experimental, statistical and clinical papers. The Joint Action Committee and its sponsors, the Committee on Trauma of the American College of Surgeons, the National Safety Council, as well as the American Association for the Surgery of Trauma, will have access to each issue for presentation of material of importance to our readers. Editorials will relate to trauma in its broadest sense.

All of the editorial consultants selected by Dr. Johnston have agreed to continue to serve. Much enthusiasm was manifest at their first meeting held during the Coronado meeting of the American Association for the Surgery of Trauma, and current plans call for another such gathering in March. A few additions have been made to provide more complete geographic and surgical specialty representation, and the Editorial Board, as now constituted, augurs well for the future. Every effort will be made to maintain a high standard of excellence. All papers submitted for publication will be reviewed independently by at least two editorial consultants. A qualified professional statistician will pass on all statistical data. From time to time surgeons of recognized standing working in the same or related fields will be invited to write brief editorial comment to accompany papers whose subject matter makes this appropriate or desirable.

Comments and suggestions from readers relative to future issues will be most welcome, and they may be addressed to the editor or given to any of the editorial consultants. Our sole aim is the publication of a journal of high standards with the widest possible spread of reader interest. Only thus can the Journal of Trauma achieve its objective: betterment in the care of the injured patient, whoever and wherever he may be.

RUDOLF J. NOER, M.D.
Editor

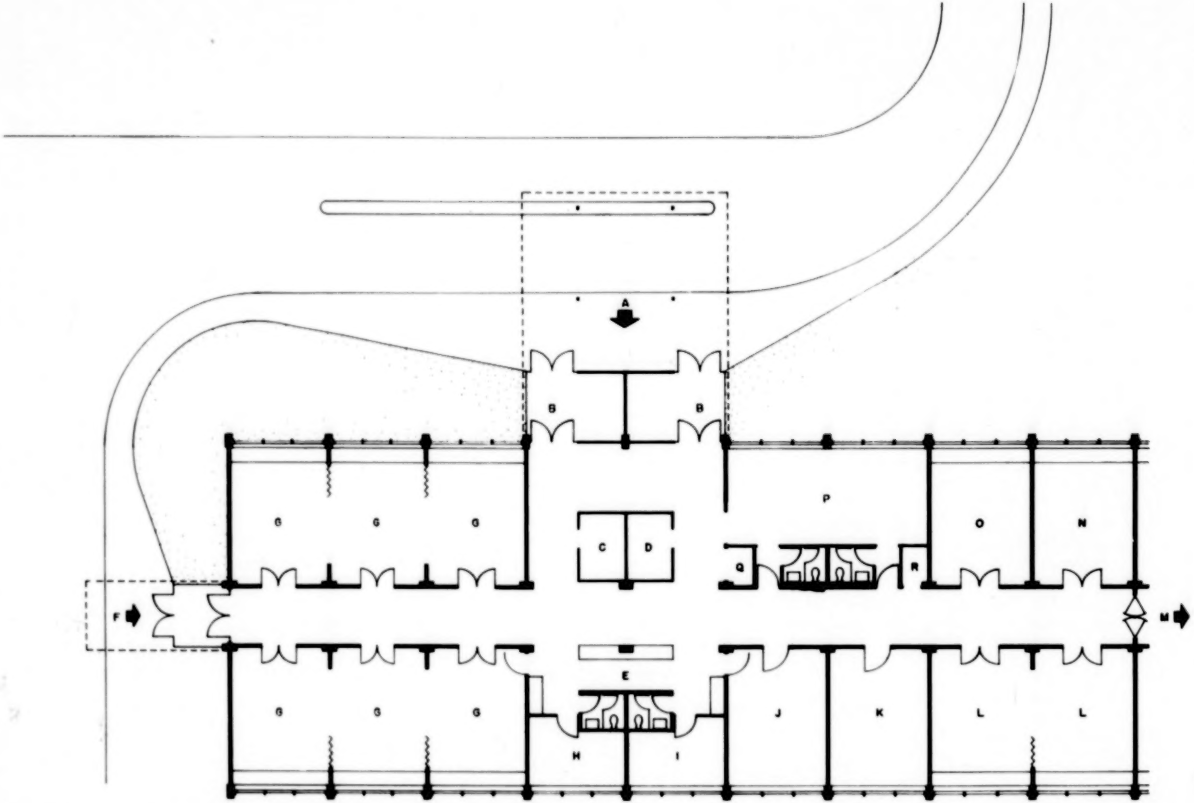

FIG. 1.A. Covered Ambulance Entrance. B. Vestibule and Stretcher Storage. C. Police. D. Admitting. E. Central Station. F. Auxiliary Entrance. G. Emergency Surgeries and Treatment Rooms. H. Utility. I. Storage. J. Observation—Recovery. K. Storage. L. Orthopedic—Plastering. M. Entrance to Hospital. N. Laboratory. O. X-ray. P. Waiting Room. Q. Wheel Chairs. R. Janitor.

AN EFFICIENT EMERGENCY DEPARTMENT WITH EXPANDING FACILITIES FOR DISASTER

KENT L. BROWN, M.D., F.A.C.S. AND GEORGE L. BROWN, B.I.D., B.A. OF ARCH.
Cleveland, Ohio

A disastrous situation is something we all fear since there is no certainty that facilities in our community hospitals can cope with it.

We read of storm whipped areas, devastating fires and similar cataclysms thankful that they did not happen to us. In many areas, excellent work has been done in disaster situations. The question is this: Could they have done better or could we do as well?

What medical preparation and architectural planning of an emergency department would expedite transition of facilities from the routine care of emergency patients to an increased potential to treat many injured?

We cannot be certain of coping with disaster. We can only do our best to be prepared.

Ideal conditions are more nearly attained when building a new hospital. However, existing hospitals can be altered better to meet the situation.

We propose to consider the problem from a new construction point of view, realizing that many of these suggestions can be adapted to any of our present emergency departments. In planning such a facility it must be kept in mind that hospitals cannot afford space sitting idle waiting for disaster.

Location of Emergency Department

A primary consideration in planning any emergency department is one of location with access to working space within the hospital proper and on the grounds. Such a department should be adjacent to a street or highway trunk to expedite transporting patients from vehicles.

Lawn or outside paved surfaces adjacent to the portals of entry are desirable for patient sorting, temporary storage of patients or equipment, or even patient treatment. As pointed out by Brown and Glover (2) fireproof tents could be pitched when additional working area is required. This, of course, is only possible in suitable seasons or climates. Tents could be stored in outside wall lockers or in free standing storage units. This space adjacent to the emergency facility can also be used for landing ambulance helicopters, for parking ambulances; or for fire department, police or army equipment.

Of paramount importance is the proximity of the emergency department to the outpatient clinic or, in some hospitals, to utility rooms or offices. These rooms are designed to be readily utilizable for emergency department overflow. Provision is made for storage of equipment in hall closets, in recessed cupboards, in corridors, or in remote areas without detracting from appearance.

Wheeled utility carts are available to supply these rooms as well as the grounds area.

The X-ray department must be conveniently located. At least some of its equipment should be within the emergency department to eliminate the need for elevators and other difficulties which may arise in moving many patients from floor to floor. Elevators are often too small to accommodate a patient, his traction devices, intravenous bottles and attendants. Or they may fail, which would cause a bottleneck in time of stress. Certainly in a disaster the main X-ray department would be used in addition to X-ray equipment in the emergency rooms.

Formal surgical suites are best located on the same floor or directly above the emergency department. It is realized, however, that these two major facilities often cannot be on the same floor, particularly in urban areas where land space is limited and hospitals must be multi-story.

First aid as well as some major surgery can be done in the emergency surgical units decreasing the immediate need for moving patients to the formal surgical division. This would eliminate some of the confusion which would otherwise exist during a disaster.

General supply and maintenance departments must be conveniently close and adequate mobile units should be readily available for transfer of materials.

Recommended Layout of an Emergency Department

A hypothetical arrangement of an emergency department for a new hospital of approximately seven hundred beds is illustrated (fig. 1).

The general shape of the department is represented as a rectangle with a wide central corridor in the long axis. The corridor gives ready access to all work and storage rooms and provides floor space for litter patients or wall space for stretcher patients. The accompanying drawing (fig. 2) illustrates a system for wall support of stretchers. These supports would be at the level of the ordinary

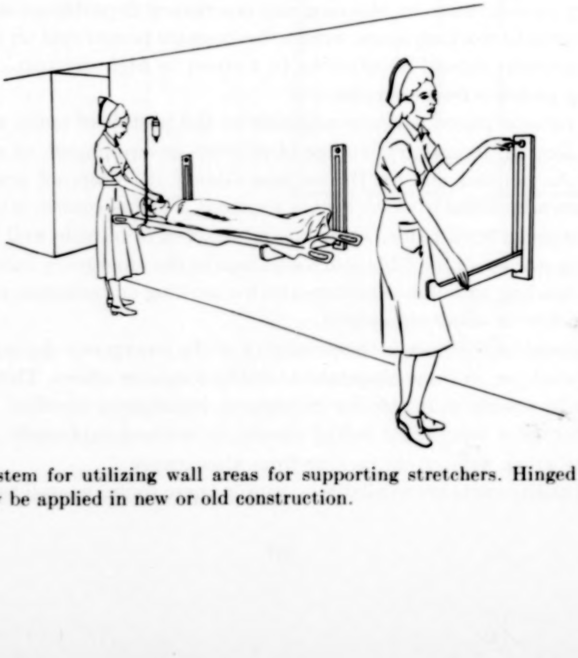

FIG. 2. System for utilizing wall areas for supporting stretchers. Hinged brackets of this type may be applied in new or old construction.

roller cart in order to make transfer of the stretcher and patient from the cart to the supports relatively easy. Straps would be used to hold patients on the stretchers.

The two main portals of entry would be placed on one side of the department. They must be prominently marked so that they may be easily found by strangers and signs should be located to direct people to the emergency department. It is most important that these entrances be located as conveniently as possible to the adjacent street or highway.

An unloading platform should have a curb with provision for a ramp to driveway level for convenience in placing patients in wheel chairs, on roller carts, or for carrying them on a stretcher. This eliminates awkward manipulation of these patients.

Steam heated pavement in the area surrounding these doors has been found to be of considerable advantage in winter weather.

The two main portals of entry would be separated by a storage space for wheeled carts and folding wheel chairs. An outside locker would also be available for the storage of stacked metal stretchers.

A desirable stretcher should be fabricated of rustproof, X-ray transparent metal. It should stack easily and compactly, be strong, light, reasonable in cost and easy to handle. A considerable number could then be stored without wasting space. Such a stretcher eliminates moving the patient several times during his treatment and simplifies handling. It is a protection to the patient and more efficient for personnel. One type of a single stretcher system now available is known as the "Transaver System." (7)

One of the two main entrances should be restricted to use of stretchers or wheel chair patients only, and the other for ambulatory patients and relatives. The admitting desk would be so located as to shunt ambulatory patients to the proper examining room and relatives to the waiting room. In time of disaster both groups could be kept outside the building while the waiting room is required for other uses.

A single entrance with automatic double doors and heated vestibule is advised for the far end of the corridor. This entrance would open onto the grounds area and be lock-controlled at the nurses' station. It would not be for general use since it is desirable to eliminate ambulatory patients and relatives from this important work area. This door could be used to dismiss routine emergency patients if desired, but would be of great advantage in time of disaster. Once a patient had received treatment in the emergency department, and provided his condition did not warrant admission to the hospital proper, he could be evacuated through this portal to the outside work area. Here he could be further observed or treated in tents or other working space. Or he could await evacuation to secondary treatment centers.

All entry locations lead to the central station. This station is centrally located so that nurses, attendants and physicians can serve the separate units efficiently. The nurses' station, police desk and admitting desks compose this section.

The remainder of the general plan is self-explanatory in the drawing and legend.

In some emergency departments space is gained by sliding or folding doors separating the surgical rooms. These can be thrown open so that several surgical suites become a common room. This increases efficiency making possible treatment of more patients by fewer personnel.

An efficient emergency department must have a communication system controlled at the main nurses' desk. There must be adequate lighting, and standby emergency lighting in case of electrical failure. Piped in oxygen as well as resuscitation apparatus must also be immediately available.

The more modern manual suction units and hand resuscitators (1) with self inflating bags to which a mask or endotracheal tube can be attached should be conveniently located about the department. An adequate supply of double airways such as the Resusitube (5) and Venti Breather (3) should be available in quantity. These devices have the advantage of easy mobility and can be carried to the patient.

A well integrated plan for rapid mobilization of an augmented staff is a necessity in time of disaster. Schneewind (6) and others have discussed personnel for the emergency department. Such considerations are beyond the scope of this paper. Our recommendations are restricted to the physical structure and items of equipment which facilitate expandability.

Observation or Recovery Ward

Standard hospital beds seem best for the observation ward. The room should be large enough to accommodate several patients. Folding blinds or curtains may be used to screen the male from the female patients when needed.

In time of disaster patients may be kept in this room while they await release, evacuation, or admission to the hospital. This allows a space for patients during the interval when less ill or nearly well patients can be discharged from the hospital to make available beds for emergency patients.

As with treatment rooms in the department, oxygen, suction and other emergency equipment should be readily available.

Waiting Room

In this section built-in benches with enclosed bases and upholstered seats may be built next to the walls on at least three sides. The top of the seat, which would be approximately six feet in length, would open toward the wall. The box support of the seat could be used as another storage space for disaster equipment. A bench of this type has a further advantage in that it can also be used to support stretchers so that patients could be temporarily housed or treated in this room.

Central Corridor

The central corridor must be wide enough to allow space for bunks or stretchers on one or both sides and still permit adequate passage for equipment and personnel.

The wall support bracket system which is illustrated adapts itself to new or old construction. This is also true of hinged-down bunks or stretchers. In new construction, steel standards may be incorporated within the walls to receive stretcher supporting brackets. In existing buildings a similar system could be devised using the standards exposed and anchored to the walls at the floor and ceiling. The stretcher supporting brackets would be demountable and kept stored when not in use.

The corridor wall space is a possible location for recessing wheeled equipment carts. They must be dust protected by a suitable covering.

Surgical Rooms

The surgical rooms have essentially similar needs as regards expandability. Recessed shelves supplied with materials over and above normal operating requirements are important. Metal base cabinets are recommended. These would provide a work surface with sinks. Wall cabinets can be installed over the base cabinets.

Metal rods attached to the wall by a hinge mechanism may be swung over the operating table to support intravenous bottles. They must be above the height of personnel. A ceiling hook over the operating table, at a height easily reached, might be used for the same purpose. Hinged rods on the side of the stretcher or operating table could be raised and held by a lock mechanism to support intravenous bottles or traction devices. A holder of this type is particularly logical for the stretcher since the patient continues to receive treatment while being transported.

Usually thin rubber mattresses are placed over the operating table or stretcher for patient comfort. In time of emergency these may be eliminated and substituted by a sterile sheet folded in three thicknesses.

Oxygen, suction, and resuscitation equipment are better when available from the ceiling rather than the wall. This eliminates stringing tubing from the wall

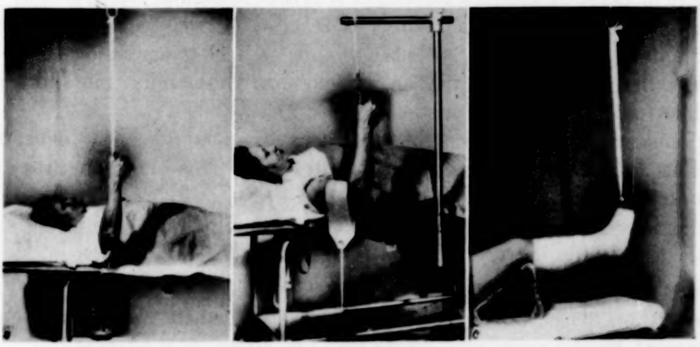

FIG. 3a. Traction applied by attaching slip knot to thumb. Two inch bandage is tied to ceiling hook above. Countertraction is obtained by fastening weight to sleeve with safety pin. b. Alternate method of applying traction when vertical side bar is attached to table. Countertraction is provided by weight attached to arm band. c. Method of holding foot with slip knot over great toe. Bandage is tied to ceiling hook. Method relieves assistant while cast is applied or leg wounds are treated.

to the patient and provides a less cumbersome working space. It also lessens the possibility ot damage to these tubes when they are in use.

Hooks extending from the ceiling are useful for supporting the arm or leg in treating certain extremity wounds or fractures. Vertical side rods with a horizontal extension at the top may be similarly used. These devices eliminate an assistant who might otherwise be required to hold the limb. Two-inch bandage may be tied with a slip knot over the great toe or thumb of the patient and held so that the arm or leg can be elevated to allow necessary treatment. The Japanese finger cot may be substituted for the slip knot. (fig. 3)

Medications are best arranged by placing those most usually required on an easily handled portable tray which has supports for the containers. They could be quickly moved about, used, and returned to a shelf or cupboard. Medication drawers could be made to slide under the operating table or wheeled cart, or be built into operating table supports.

Wheeled burn carts and plaster carts must be in several rooms. They should be supplied for a sizable number of patients. (2) If at all possible these carts should be kept for the most part in the department store room. However, they can also be recessed in walls, or alcoves, and dust protected. Materials and packaging must be such that burn dressings and medications will stand prolonged storage.

Needles, syringes, certain dressings, splints and other small pieces of equipment can ordinarily be stored in drawers or cupboards. It is advised that those items which must be used sterile be placed in individual sterile packs so that they can be used directly from this package or container. Periodic routine inspection of all stored equipment and medication is essential.

Orthopedic Room

The orthopedic or plastering room in addition to similar equipment in other surgical suites should have a number of traction devices. McGaw (4) has designed a device which solidly attaches to ends or sides of emergency room carts or tables. (fig. 4) This can be applied for temporary immobilization and traction as well as for some specific reductions.

Patients may be moved from the emergency room to the X-ray department, and films taken, without disturbing the traction. This eliminates the use of temporary splints in certain situations.

Splints of various types must be available with many more in adjacent storage spaces.

Sinks must be equipped with plaster traps.

The orthopedic rooms should be in close arrangement with the emergency department X-ray room.

Utility Room

Efficient arrangement and satisfactory equipment are most important in this room since it is used by all treatment rooms and, in fact, by any area where patients are assembled or treated.

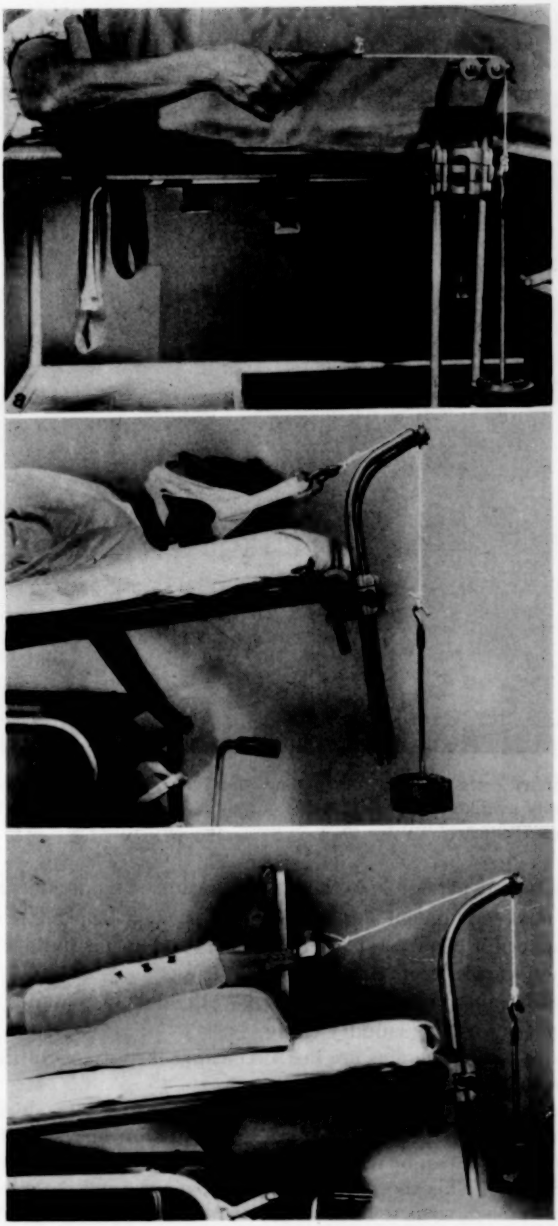

FIG. 4a. Side attachment of adjustable pulley traction device. Japanese finger cot applied to thumb with countertraction on upper arm as used in Colle's fracture. b. Adjustable pulley traction applied to end of cart for emergency immobilization and traction for cervical injuries. Head end of cart is elevated for countertraction. X-rays may be taken without disturbing the head halter. Note the elevating apparatus on cart. c. Traction device with sponge rubber and elastic dressing applied to leg. Used for temporary immobilization, and traction to injuries of the tibia, femur, hip and pelvis. Countertraction is applied by elevating table.

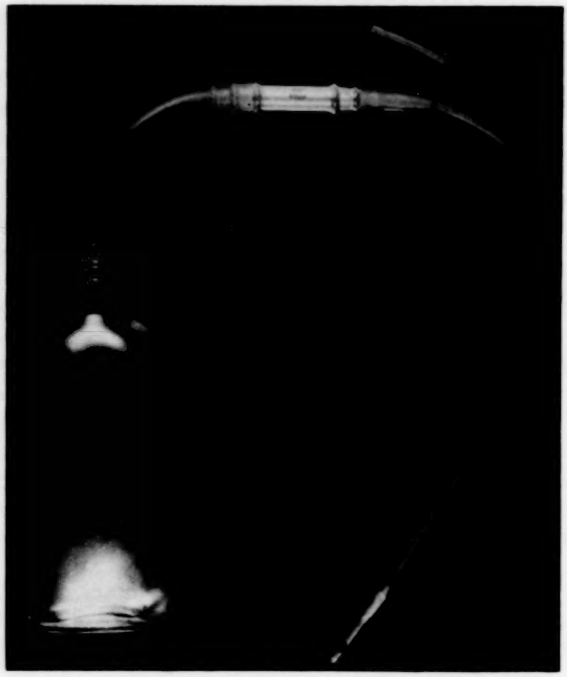

FIG. 5. Urinary catheter with transparent container attached. Is packaged sterile so that it is readily available as a unit. Urine output can be easily visualized while patient is on a stretcher or cart.

It must be readily accessible to the nurses' station. A moderate sized autoclave is sufficient since equipment is prepared and packaged ahead. Essential is an adequate hopper for disposal of thick materials and urine, as well as a bedpan sterilizer, linen warmer and refrigerator.

There must be sinks and many cupboards with adequate counter space besides a linen hamper or suitable laundry chute.

Medicines are stored here as are instrument packs in excess of those placed in other treatment areas.

Urine containers with catheters attached (fig. 5) should be sterilely wrapped and ready for immediate use. These are important in burned or badly injured persons. The catheter can be inserted and is attached by a short tube to a plastic container or bottle. This receptacle would be over the patient's thigh or at his side on the stretcher, so as to be readily observable for urine output.

Central Station

The central station is in three divisions. Next to the utility room is the nurses' station with the main communication system and other control equipment. Adequate desk space should be furnished nurses and physicians.

The opposite half of the station is devoted to two enclosed desk spaces. One is for the police department, the other for the admission of patients. The latter should be directly adjacent to the waiting room. This places both desks in relatively close access to the main entrance.

Summary

A presentation is made of the requirements of an efficient hospital emergency department from a medical and architectural point of view.

Methods and devices for expanding space and facilities to meet a disaster situation are considered.

Equipment suitable for storage and methods of storage are discussed.

Photographs and drawings are used to illustrate.

BIBLIOGRAPHY

1. Ambu Resuscitative Unit With or Without Suction. Air Shields Corporation, Hatboro, Penna.
2. Brown, K. L. and Glover, D. M., Initial Treatment of Burns in Mass Casualties, J.A.M.A., **165:** 643-646 Oct. 12, 1957.
3. Lee, Wm. L. Jr., et al, Evaluation of the New Oral Resuscitator for Expired Air Artificial Ventilation, J.A.M.A., **169:** 33–35 Jan. 3, 1959.
4. McGaw, W. H., St. Luke's Hospital, Cleveland, Ohio, personal communication. Equipment available at Pemco, Inc., Cleveland, Ohio.
5. Safar, Peter and McMahon, Martin, Mouth-to-Airway Emergency Artificial Respiration, J.A.M.A., **166:** 1459–1460 March 22, 1958.
6. Schneewind, John H., The Need for an Active Teaching Program in the Emergency Service, Am. J. of Surg., A.A.S.T. number, p 400, 1958. (**97:** 400–406, 1959).
7. The Transaver System, manufactured by Brooks and Perkins, Inc., Detroit, Mich., distributed by General Electric Corp., Milwaukee, Wis.

BLUNT ABDOMINAL TRAUMA

Review of Cases Admitted to a General Hospital Over a 10 Year Period

HAROLD E. KLEINERT, M.D. AND JOSÉ ROMERO, M.D.

Serious non-penetrating abdominal trauma presents a difficult diagnostic challenge. The usual clinical evidence denoting rupture or other injury of intra-abdominal organs is commonly absent or incomplete because of shock or unconsciousness. More obvious associated injuries such as fractures, thoracic or cranial trauma may lull the inexperienced surgeon into a false sense of security. Only a high index of suspicion based upon experience can avoid the tragedy consequent upon too long delayed abdominal exploration.

This presentation, an analysis of 161 cases with blunt abdominal trauma, was undertaken with the hope of learning better ways for earlier diagnosis and more appropriate treatment. Only by this means can we hope to decrease the high mortality now associated with these injuries.

ETIOLOGY

The distribution of etiological factors is listed in Table I.

ORGANS INJURED

See Table II. The most frequently injured intra-abdominal organ was the spleen, accounting for 57 of the cases. Most of these were associated with other injuries. See Table III. Fractured ribs were associated with injury to the spleen in 15 cases (26%).

Twenty six patients suffered liver injuries. (See Table IV).

Twenty-four patients suffered injuries of the kidney (see table V). Thirty-five of these were vehicular or vehicular pedestrian injuries.

Twenty-eight of 32 patients with bladder injury had an associated pelvic fracture. (See table VI).

The gastro-intestinal tract was ruptured in 14 patients (see table VII). There were 33 miscellaneous injuries, frequently associated with other injuries. (See table VIII).

DIAGNOSTIC CRITERIA INDICATING NEED FOR EXPLORATION

An accurate history as to the type and extent of trauma sustained is important. However, this cannot always be correlated with the severity of the injury. For example, while one patient fell from a bed and suffered a ruptured spleen, another received only a contusion of the kidney after a 30 ft. fall from a scaffold.

From the Department of Surgery, University of Louisville, and the Louisville General Hospital.

Read before the Nineteenth Annual Session of The American Association for the Surgery of Trauma, Bretton Woods, New Hampshire, September 24–26, 1959.

TABLE I

Etiology of Cases of Non-penetrating Abdominal Trauma

Vehicular Accidents			137
Driver	21		
Passenger	23		
Pedestrian	43		
Non Specified	49	(Probably most were passengers)	
Jumped from moving truck	1		
Falls			17
(Varying from a 40 ft. suicide jump to a fall from bed)			
Kicked			4
Struck with axe handle			1
Hit by steam shovel			1
Unknown			1
Total			161

TABLE II

Abdominal Organs Injured

Spleen		57
Kidney		44
Urinary Bladder		32
Liver		26
G. I.		14
Mesentery		10
Retroperitoneal Hematoma		7
Ruptured Diaphragm		6
Large Abdominal Blood Vessels		5
Abdominal Aorta	1	
Vena Cava	1	
Lumbar Arteries	1	
Superior Mesenteric Vein	1	
Inferior Mesenteric Vein	1	
Dermoid Cyst of Ovary		1
Abortion—Traumatic		2

TABLE III

Trauma to the Spleen

			Died
Spleen only		19	
Immediate rupture	18		0
Delayed rupture	1		1
Spleen and other intra-abdominal organs only		7	2
Spleen and rib fractures only		6	1
Spleen, multiple fractures, and/or head injuries		20	5
Spleen, other abdominal organs, multiple fractures and/or head injury		5	4
Total		57	13
Mortality 23%			

TABLE IV

Liver Injuries

		Died
Liver only	4	1
Liver and spleen	3	1
Liver, one intra-abdominal organ, fractures and/or head injuries	15	9
Liver, two or more intra-abdominal organs, fractures and/or head injuries	4	3
Total	26	14
Mortality 54%		

TABLE V

Kidney Injuries

			Died
Kidney injury only		15	
Contusion	8		0
Rupture	7		2
Kidney injury with rib fracture only		8	
Contusion	7		0
Rupture	1		0
Kidney injury with associated multiple fractures and/or head injuries		9	
Contusion	7		0
Rupture	2		0
Kidney injury with other abdominal injuries, multiple fractures, and/or head injuries		12	
Contusion	4		0
Rupture	8		4
Total		44	6
Mortality 13%			

TABLE VI

Bladder Injuries

			Died
Bladder only		2	
Contusion	1		0
Intraperitoneal rupture	1		0
Bladder and Pelvic Fracture only		11	
Contusion	4		0
Intraperitoneal rupture	4		1
Extraperitoneal rupture	3		0
Bladder, Multiple Fractures and/or Head Injuries		13	8
Contusion	3		
Intraperitoneal Rupture	4		
Extraperitoneal Rupture	6		
Bladder, other Abdominal Organs, Fractures and/or Head Injuries		6	4
Contusion	1		
Intraperitoneal	3		
Extraperitoneal	2		
Total		32	13
Mortality 41%			

TABLE VII

Gastrointestinal Tract Trauma

			Died
Gastrointestinal Tract only		5	0
Jejunum (all near ligament of Treitz)	3		
Ileum	2		
Gastrointestinal Tract and other Intra-abdominal organs		3	0
Duodenum and stomach	1		
Stomach	1		
Jejunum	1		
Gastrointestinal Tract, Fractures and/or Head Injuries		3	3
Stomach	1		
Ileum	2		
Gastrointestinal Tract, other Intra-abdominal organs, Fractures and/or Head Injuries		3	2
Ileum and jejunum	1		
Ileum	2		
Total		14	5
Mortality *36%*			

Ruptured spleen, liver or pancreas frequently result from being thrown into the steering wheel. Patients thrown from a vehicle frequently suffer multiple fractures and head injuries.

Among the symptoms, pain is the one most commonly associated with intra-abdominal injury. The site of pain may aid in localization. Shoulder and upper abdominal pain are usually present with a ruptured spleen or liver, while rupture of the urinary bladder more often gives constant lower abdominal pain. A continued desire to void may point to a ruptured bladder or injured urethra. A history of vomiting blood, passing blood from the anus or urethra all tend to indicate and localize the site of injury. Half of the patients with a ruptured diaphragm complained of chest pain.

A careful and sometimes repeated physical examination usually established the diagnosis. Skin marks, abrasions or tire tread marks over the abdomen, pelvis or lower chest are evidence of severe trauma and indicate that major intra-abdominal organ injury has probably occurred. Tenderness in the left upper quadrant or flank was often observed with a ruptured spleen though this was by no means constant. Patients with injury to the kidney often exhibited mid back tenderness. All too frequently, abdominal tenderness was generalized and was of no value in attempting to localize the injury. Increased abdominal muscle resistance and rebound phenomenon were commonly present in the conscious patient. Peristalsis was absent to diminished in 40% of the patients.

Signs of shock or impending shock accompanied those of peritoneal irritation. Occasionally the patient in severe shock with no blood pressure exhibited no positive abdominal findings until vigorous antishock measures had been in-

TABLE VIII

Miscellaneous Abdominal Injuries

		Died
Mesentery—(All with associated injuries)		
Contusion	3	
Avulsion	2	
Laceration	5	
Total	10	4
Mortality	40%	
Retroperitoneal Hematoma		
Associated intra-abd. injuries	3	1
Associated intra-abd. injuries, fractures and/or head injuries	4	3
	—	–
Total	7	4
Mortality	57%	
Pancreas		
Traumatic pancreatitis	1	0
Rupture of pancreas—assoc. intra-abd. injuries and fractures	3	0
	—	–
Total	4	0
Mortality	0%	
Diaphragm		
Rupture diaphragm, multiple fractures	2	0
Rupture diaphragm, other intra-abd. injuries, multiple fractures	4	2
	—	–
Total	6	2
Mortality	33%	
Blood Vessel		
Major intra-abdominal blood vessel injury (all with other intraabdominal injuries)	5	3
Mortality	60%	0
Dermoid Cyst—associated fracture	1	0

stituted. Similarly the unconscious patient often had lack of abdominal findings on physical examination. Some patients with a small slow intra-abdominal hemorrhage or small perforation of a viscus did not have apparent intra-abdominal injury on the initial physical exam. It is this group of patients, those unconscious, those in severe shock, and those with a slow hemorrhage or a small perforation that require repeated physical examination in order to establish the diagnosis.

Evidence of fractured left ribs suggests rupture of the spleen. Similarly a fractured pelvis points towards rupture of the urinary bladder. The presence of blood on the examining finger after rectal exam may indicate perforation of the rectum, colon or small bowel. Bloody urine indicates kidney or bladder injury. Bright red blood from the urethra suggests rupture of the urethra. All patients were catheterized.

The most helpful laboratory aids were the cystogram, intravenous pyelogram and retrograde pyelogram. Injection of a known amount of sterile saline through a catheter into a possibly ruptured bladder and measurement of the amount of aspirate can be misleading and dangerous. A cystogram is the most reliable method for diagnosis of a ruptured urinary bladder. All patients with suspected renal injuries had an intravenous pyelogram. Where poor visualization was obtained or if results were equivocal retrograde pyelograms were done.

Flat plat of the abdomen, lateral decubitus and upright x-ray views of the abdomen were not routinely done. Where the diagnosis was in doubt and if the patient's general condition warranted these studies they were performed. Displacement of the stomach bubble, serrations on the lateral margin of the stomach and elevation of the left diaphragm are indicative of rupture of the spleen. Of 8 cases of splenic rupture that had x-ray examination, 3 were interpreted as diagnostic of a ruptured spleen and 3 others were slightly suggestive. Loss of the psoas shadow suggests renal injury or retro-peritoneal hematoma. Of 6 cases of perforation of the gastrointestinal tract that had x-ray examination, free air was revealed in but one.

The blood count is not particularly helpful. The red cell count, hemoglobin and hematocrit remain relatively unchanged during the first few hours of acute hemorrhage. Most of our patients had only minor changes on the initial blood count. An elevated white blood count was a frequent finding with rupture of the spleen, but it occurred occasionally in other intra-abdominal organ injuries, particularly injury to the liver. Of 45 patients with splenic rupture, the preoperative white blood count was elevated above 20000/cu mm. in 25.

Paracentesis employed 36 times in this series, was only moderately helpful. Fifteen taps revealed blood. One of these was incorrectly positive in that at exploration only a large retro-peritoneal hematoma was found. A negative tap occurred on 21 occasions. On exploration 19 of these patients had blood, urine or intestinal contents in the peritoneal cavity. These findings emphasize the danger of diagnostic conclusions based on negative taps.

SPECIFIC ORGAN INJURIES

Spleen (57)

Rupture of the spleen was associated with fractured left ribs in 25% of the cases. Most of the patients complained of pain, usually in the left upper quadrant. Occasionally chest and shoulder pain were recorded. Nausea and vomiting were present in a few cases. Findings on physical examination were left upper quadrant and left flank tenderness. Peristalsis was usually diminished or not present. Signs of shock, lowered blood pressure and elevated pulse rate were

TABLE IX

Average Length of Hospital Stay for Patients That Survived

Organ Injured	Alone	Associated with Other Injuries
Spleen	7.8 days	30 days
Liver	16 days	27 days
Kidney	7 days	10 days
Bladder	9 days	20 days
G.I. Tract	9 days	15 days
Diaphragm	No cases	22 days
Pancreas	No cases	37 days
Mesentery	No cases	41 days
Retroperitoneal hematoma	No cases	25 days

common. Abdominal paracentesis, usually performed in the left upper quadrant was done in 21 cases and blood was obtained in eight.

Splenectomy is the only safe method of treating a traumatized spleen. The danger of secondary rupture precludes any attempt at splenic repair. Of the 57 patients with injury to the spleen, laparotomy and splenectomy was performed 56 times. Of this operative group 44 patients survived. One patient entered the hospital with no B.P. did not respond to therapy and expired prior to celiotomy. Of the 13 deaths, 9 entered the hospital with a blood pressure of 70 or less. 12 patients had associated fractures and/or head injuries and of these, 6 had multiple intra-abdominal organ injuries. The average hospital stay of patients is listed in Table IX.

Liver (26)

Of the 26 liver injuries of this series, 19 were either passengers or the driver of a car, 6 were pedestrians struck by a vehicle, and one fell from a scaffold. Twenty-three patients either had no blood pressure or a systolic pressure of below 100 on admission. All of the conscious patients not in profound shock had abdominal tenderness. Six patients had no blood pressure and in this group a soft abdomen on palpation was a common finding. Absent bowel sounds were frequently recorded.

Paracentesis, done on 9 patients, was positive for bloody fluid in 6. Because of the gravity and urgency of the injury, x-ray of the abdomen was not performed except where indicated by other associated injuries.

86% of the patients with liver injuries had associated multiple injuries. There was one death in the patients with liver injury only, occurring in a 36 year old male who entered the hospital with no blood pressure. At operation 1 hour and 15 minutes after injury the liver was found to be completely fragmented, making any type of repair or resection hopeless. The patient died in the operating room.

Nine cases were associated with rupture of the spleen and 6 of these cases had other associated injuries. Of the 3 patients with rupture of only the liver and spleen, one died. This patient had no blood pressure or heart beat; immediate thoracotomy, cardiac massage and transfusion were performed on the stretcher. Heart beat was restored but the patient succumbed.

Fifteen cases were associated with multiple fractures and/or head injuries. Nine of these patients died. Four patients had 3 or more abdominal organs injured as well as fractures and/or associated head injuries. Of this group only one patient lived.

Principles followed in treating liver injuries are early control of hemorrhage by occluding the porta-hepatis immediately after opening the peritoneal cavity. Viable liver tissue is re-approximated. If any "pocketing" occurs deep to the repair, a drain is inserted into this pocket. Packing should not be used since free exit must be provided for bile and blood. If damage is extensive and enough normal liver tissue remains to sustain the patient, resection of the fragmented and ruptured liver is performed. Obviously extensively fragmented and nonviable liver tissue must be excised.

Massive antibiotic therapy is started in the operating room.

An example of the severely injured patient who can be salvaged was a young white female who entered with a blood pressure of 100/70 and with marked abdominal tenderness. Operation performed 2 hours and 45 minutes after injury revealed a fracture through the right lobe of the liver extending into the gallbladder bed, a complete tear through the body of the pancreas, rupture of the splenic vessels and two 7 centimeter longitudinal tears located both anteriorly and posteriorly extending from duodenum into the stomach, necessitating resection of this portion of the bowel. Despite the multiple severe injuries she recovered as a result of prompt and expeditious treatment.

Nearly all of the patients that lived required numerous transfusions.

Of the patients that reached the emergency room alive the mortality rate was 54%. See Table IX for average hospital stay of patients that survived.

Kidney (44)

Of the 44 patients with kidney injuries, 35 were vehicular or vehicle pedestrian accidents. The urine was bloody or numerous blood cells were found on urinalysis in all cases. Occasionally a mass was palpable in the flank. In all suspected cases of kidney injury intravenous pyelogram was performed. Flat x-ray of the abdomen may sometimes reveal obliteration of the psoas shadow. Cystograms were done if a ruptured bladder was suspected.

Only severe kidney lacerations will require operation. Bleeding is usually self limited by the kidney capsule if the tear is intracapsular and by Gerota's fascia if the tear is extracapsular. Accordingly, conservative treatment, consisting of antishock measures, tube intestinal decompression, antibiotics, and frequent re-examination was employed. If continued bleeding or signs of shock persisted, if a hematoma did not absorb or if a perirenal abscess developed, operation was undertaken.

There were fifteen patients with injury to the kidney only. Thirteen were treated conservatively. One patient who entered in shock, did not respond to conservative therapy, and died 3 hours later. Of the 2 patients operated on, one death occurred, that of a 27 year old female who had extravasation of dye on IVP. She was treated conservatively for 14 days, and then had evacuation of a large hematoma from the perirenal space. Seven days after this, severe hemorrhage occurred for which a right nephrectomy was performed. The patient expired 2 days later.

Eight cases were associated with rib fractures. Seven were treated conservatively. One required drainage of a perirenal hematoma 11 days after admission. All 8 survived. Nine patients with associated multiple fractures were treated conservatively. All survived.

Twelve patients had other abdominal injuries, often with associated head injuries and fractures. Four patients in this group expired, 2 in the operating room and the other 2 before operation could be undertaken. One patient in this group had bilateral kidney rupture. The most frequently associated intra-abdominal injury was rupture of the spleen which occurred in 5 patients.

Of the 44 patients there was a total of 6 deaths with a mortality rate of 13%. See Table IX for average length of hospital stay.

Urinary Tract (32)

All 32 cases of urinary tract injury had bloody urine. Twenty-three of them had a rupture of the bladder. Diagnosis was confirmed by cystogram in 18 cases. Two patients suspected of having a ruptured bladder by injection and aspiration of sterile saline had confirmation of the injury at operation. Intravenous pyelograms were employed when kidney injuries were suspected. Suprapubic pain and lower abdominal tenderness were common, and lower abdominal "rigidity" was recorded in several cases. Two patients with intraperitoneal rupture had shoulder pain.

Only 2 patients had injury limited to the bladder. One of these patients had been kicked in the abdomen. He entered the hospital with lowered blood pressure, abdominal tenderness, distension and absent bowel sounds. At operation he was found to have a 6 cm. intraperitoneal laceration of the bladder. The other patient had a contusion to the bladder.

Eleven patients with bladder injuries had as the only associated injury, pelvic fracture. In this group there were 4 bladder contusions, 3 extraperitoneal ruptures, and 4 intraperitoneal bladder ruptures. (See Table VI). One death occurred, that of a 72 year old man run over by a car, who entered the hospital in shock. The pelvis was grossly flattened. He died one hour and 50 min. after admission.

Thirteen cases of bladder injury had associated multiple fractures and/or cranio-cerebral injury. Eight patients in this group succumbed. All but 2 of this group entered the hospital in shock with a systolic blood pressure of less than 70 mm. of mercury. One patient who expired was an 80 year old female who had fractures of the pelvis, tibia and fibula and rupture of the urinary bladder as evidenced by extravasation of dye on cystogram. The patient and her family steadfastly refused surgery and she expired 7 days after admission to the hospital.

Six cases of bladder injury had other intra-abdominal organ injuries and associated multiple fractures. Three had liver fractures and 2 had fractures of the spleen. All patients were in severe shock. Three patients with no blood pressure had no special studies to demonstrate bladder injury. One died shortly after admission, prior to operation. Another with a fractured liver, spleen and craniocerebral injury died in the operating room. The third, with a bilateral pelvic fracture, multiple ruptures of the small bowel and a fractured femur died two days after admission. Two patients in this group lived. One that survived was a 17 year old female who had an associated fracture of the coccyx, fracture of the pelvis, fractured right tibia, fractured left femur and a skull fracture.

Recovery from a ruptured urinary bladder requires prompt surgical care. Undrained urine and continued soilage from either an intraperitoneal or extraperitoneal rupture is extremely toxic and not compatible with survival. When present, protruding spicules of bone from the fractured pelvis are removed. The rupture of the bladder is repaired, and a suprapubic cystostomy tube is inserted. If the rupture is extraperitoneal the space of Retzius is drained. Bladder rupture was associated with multiple injuries in 94% of cases. Of the 23 cases of bladder rupture laparotomy was performed 21 times. The over all mortality in the series of 32 cases was 41%.

GASTROINTESTINAL TRACT INJURIES

All fourteen patients with gastrointestinal perforation (See Table VII) had abdominal tenderness. Eight complained of abdominal pain. Slight abdominal distension and abdominal rigidity were present in about ⅓ of the cases. Peristalsis was recorded as absent in 6. Seven patients were in shock on admission. Aspiration of a nasogastric tube revealed bloody fluid in 3 patients. Paracentesis, performed on 3 patients, was negative.

When the perforation is small, simple repair is performed. Where extensive damage exists resection and anastomosis is the procedure of choice. Although a perforation is found and repaired the entire bowel must be examined for the possibility of multiple perforations.

Gastrointestinal Tract (14)

Five patients with only gastrointestinal tract perforation survived.

Two patients with rupture of the ileum had associated multiple fractures, both survived. One of these was a 72 year old male pedestrian struck by an automobile, who suffered a complete transection of approximately 12 inches of ileum where a truss was violently compressed against his inguinal hernia. Resection and anastomosis was performed.

Three patients with perforation of ileum, jejunum or both had other intra-abdominal organ injuries and multiple fractures. All entered the hospital in severe shock. One expired in the operating room, the other 2 shortly after operation.

Two patients with rupture of the stomach had associated injuries. One was a suicide attempt who jumped 40 feet. He expired shortly after admission. The other patient expired 2 days after operation.

One patient had a rupture of the stomach and duodenum, of the liver, pancreas and splenic vessels. A partial gastric and duodenal resection, partial pancreatectomy, splenectomy and repair of the liver was performed. The patient survived.

In this group of 14 patients there were 5 deaths with an over all mortality rate of 36%.

Pancreas (4)

The 4 cases of *pancreatic trauma* all had abdominal pain. Abdominal tenderness was marked. Bowel sounds are recorded as absent in 2 of the cases. One patient operated on 3 days after injury was found to have a traumatic pancreatitis. The pancreas was very large and indurated. The omentum and mesentery exhibited fat necrosis. Previous paracentesis was negative and serum amylase had not been diagnostically elevated. Paracentesis performed on 2 of the traumatic ruptures of the pancreas revealed blood. The 3 cases with traumatic rupture of the pancreas had other intra-abdominal organ injury.

Rupture of the pancreas was treated by excision of that portion distal to the rupture, closure of the proximal portion of the injured pancreas and insertion of multiple drains. All 4 of these patients survived.

Mesentery (10)

Of ten patients with trauma to the mesentery, all suffered other trauma. All patients exhibited a tender abdomen. Paracentesis, performed 3 times revealed bloody fluid in each instance.

One patient had an avulsion of the mesentery from the ileum, necessitating resection of the ileum. This was the only case in which injury to the mesentery alone impaired circulation of the bowel sufficiently to require resection of the bowel.

Two patients had laceration of major mesenteric veins, one of the superior mesenteric vein, the other of the inferior mesenteric vein. There were multiple other associated injuries and massive intraperitoneal hemorrhage. The superior mesenteric vein was repaired; the inferior mesenteric vein ligated. These two patients survived. Lacerations of the mesentery are repaired to prevent internal hernias.

Retroperitoneal Hematoma (7)

Seven patients had a large retroperitoneal hematoma, excluding those patients with kidney injuries. Most of the patients complained of pain and had tenderness on abdominal examination. X-ray of the abdomen, performed in one case, revealed a diminished psoas shadow and displacement of the stomach bubble. Blood on paracentesis was obtained in one case with an extensive retroperitoneal hematoma extending into the sigmoid colon. Six patients had other intra-abdominal injuries. Four patients had either vertebral or pelvic fractures. One of the patients that expired had a massive retroperitoneal hematoma secondary to avulsion of the lumbar arteries from the aorta. There were 4 deaths, all with extensive multiple abdominal organ injuries, 2 with fractures and one case a severe head injury.

Traumatic thrombosis of the aorta occurred in a 56 year old male who ran his car into a parked truck. As he was "booked" at the police station his legs became paralyzed. On admission he had a systolic pressure of 80, abdominal tenderness and absent femoral pulses. At operation he was found to have a crush injury of the abdominal aorta with an intramural hematoma completely occluding the lumen. During insertion of a nylon aortic graft, cardiac arrest occurred and he died a few hours later.

One patient had a laceration of the inferior vena cava, of the liver, rib fractures and a head injury. He received 6,000 cc. of blood and expired on the operating table.

Another interesting patient was a 39 year old female admitted with a fractured humerus. After admission she developed abdominal pain, nausea and vomiting. Examination revealed signs of an acute abdomen. At operation peritoneal surfaces were covered with oily sebaceous material and hair, the origin being a large ruptured dermoid cyst of the right ovary. She had a prolonged period of adynamic ileus but eventually recovered.

Diaphragm (16)

Rupture of the diaphragm occurred in 6 instances (Table VIII). Three patients had upper abdominal tenderness, most marked on the side of rupture. Four patients had a systolic blood pressure below 80. Three patients complained of chest pain. Chest x-ray done in 5 cases revealed evidence of a ruptured diaphragm in 3 instances. One patient who had no associated intra-abdominal injury was found to have peristalsis audible on auscultation of the left chest. Left thoracotomy revealed a long laceration of the left diaphragm. The other 5 patients were explored with a right or left paramedian incision. Two patients who entered with no blood pressure and with multiple injuries expired. The overall mortality was 33%.

DISCUSSION

The conscious patient, complaining of abdominal pain, after blunt abdominal trauma presents a difficult diagnostic problem. Even more challenging is the situation posed by the unconscious patient or the one in severe shock with multiple associated injuries.

The history of the type and extent of trauma can often be correlated with the severity and extent of injury. It must be remembered, however, that relatively minor trauma, such as a fall from a bed, a fall off a tricycle, or even down a few steps can produce serious intra-abdominal organ injury.

A history of vomiting blood, or voiding blood may help localize the injury. Pain is the single, most valuable clue. A few patients with ruptured spleen and liver had shoulder pain. Half of the patients with a ruptured diaphragm had chest pain. A constant lower abdominal pain with a desire to void may indicate a rupture of the urinary bladder.

Physical examination is by far the most valuable diagnostic aid. Occasionally repeated physical examinations are necessary and of great value.

Blood pressure and pulse may be normal on admission and later signs of shock may appear as evidenced by slight lowering of blood pressure and elevation of pulse rate. Abrasions or tire marks may indicate the site of major trauma. Fractured left lower ribs were frequently associated with rupture of the spleen. Fractures of the pelvis were frequently associated with rupture of the urinary bladder. Any patient with evidence of fractured left ribs or a fractured pelvis should be suspected of having spleen or bladder respectively injured.

Bloody nasogastric aspiration may indicate gastroduodenal trauma, often however, it is the result of swallowing blood from the nasopharynx. Blood in the rectum suggests large bowel or possible small bowel injury. Bloody urine indicates a urinary tract injury. Grossly, bloody urine associated with inability to pass a catheter is evidence of a torn urethra.

Practically all conscious patients with intra-abdominal injury had abdominal tenderness, this being the most frequent and constant sign. Peristalsis is usually absent to diminished. Often there is an increase in involuntary abdominal musculature resistance and the rebound phenomenon is present. Abdominal tenderness, abdominal wall rigidity and diminished peristalsis, together with signs of shock were the most common signs of intra-abdominal injury.

In the emergency room an adequate airway is established. A flailing chest must be stabilized in order to obtain adequate respiratory exchange. Blood is immediately drawn for laboratory study and for type and cross match. Shock is combated by the use of saline and plasma expanders, while waiting for whole blood. Positioning the patient will help combat shock. Severely injured patients are moved directly to the operating room from the admitting room.

If x-rays are to be done a physician should be in constant attendance. X-ray of the abdomen may reveal free air, indicating rupture of the gastrointestinal tract. Occasionally a rupture of the spleen and retroperitoneal hematoma is diagnosed on x-ray examination of the abdomen; as a rule however, these examinations are not necessary. Csytogram is a valuable aid in diagnosing a ruptured urinary bladder. Radioopaque dye is injected into the bladder through a catheter and an x-ray taken; following this the dye should be drained from the bladder and another x-ray taken to demonstrate a small extravasation that may have been obscured by the distended bladder. An intravenous pyelogram is done on all suspected kidney injuries and if necessary a retrograde pyelogram is done.

The blood count is not of much value early in hemorrhagic shock. A white blood count was found to be of more value than a red cell count but certainly not diagnostic. A white blood cell count was frequently elevated in rupture of the spleen and only occasionally in other intra-abdominal organ injuries.

Of patients with a ruptured spleen, 45 had a blood count; twenty-five cases had an elevation above 20,000 and 33 had an elevation above 15,000.

Paracentesis, when used, was correct in 39% of the cases and was somewhat disappointing as a diagnostic aid. A negative abdominal paracentesis is to be regarded as having absolutely no diagnostic value. A positive paracentesis, however, can be interpreted as diagnostic of intra-abdominal injury. Other

TABLE X
Mortality Table

1 organ alone	8%
2 organs	38%
3 organs or more	70%
Total Mortality, Entire series	24%

series have reported a much higher incidence of positive abdominal paracentesis. Many of our patients had the tap performed just once, only in the quadrant of maximum tenderness, no doubt accounting for the low incidence of positive results. Abdominal paracentesis can be a valuable aid and should be employed in all four abdominal quadrants. A needle with a blunt end and a hole on the side is ideal for abdominal paracentesis.

The mortality rate rapidly increases as additional abdominal organs are injured. (See Table X).

In final analysis, if well founded evidence suggesting abdominal trauma exists, exploration must be done. A negative exploration through a small abdominal incision will be far less injurious than failure to explore a patient who has suffered major intra-abdominal injury. During the years 1954 to 1959, 10 negative abdominal explorations were performed for suspected intra-abdominal organ injury secondary to nonpenetrating trauma. All patients recovered without complications. The positive explorations have been enumerated in the paper; it can safely be said that only prompt and thorough operative treatment saved the lives of those who survived.

CONCLUSION

1) The results of 161 patients with nonpenetrating abdominal trauma over the years 1948 to 1959 are analyzed.

2) With injury to only one abdominal organ, the mortality rate is small and the hospital stay relatively short. The mortality rate climbs rapidly as additional injuries occur, and the hospital stay for the survivors is long.

3) An overall mortality rate of 24% leaves much to be desired and emphasizes the need for better diagnostic and therapeutic attack upon the problems presented by blunt abdominal trauma, in which 71% of the cases had multiple injuries.

4) If doubt exists regarding perforated or ruptured abdominal organs, a small abdominal incision adds little hazard to the patient. It is the only hope of survival if major injury to abdominal organs has occurred.

REFERENCES

1. Estes, W. L., Jr. Present day problems in nonpenetrating abdominal trauma. Bull. Am. Coll. Surgeons, **39:** 11–18, (Feb.) 1954.
2. Estes, W. L., Jr., Bowman, T. L. and Meilicke, F. F. Nonpenetrating abdominal

trauma (With special reference to lesions of the duodenum and pancreas). Am. J. Surg., **83:** 434–452, 1952.

3. Hilsper, J. T. Nonpenetrating wounds of the abdomen. Am. J. Surg., **90:** 580–587, 1955.
4. Morton, J. H., Henshaw, J. R. and Morton, J. J. Blunt trauma to the abdomen. Ann. Surg., **145:** 699–709, 1957.
5. Prather, G. C. Injuries of the bladder. J.A.M.A., **154:** 205–207, 1954.
6. Spenell, H. M. and Ware, E. W. Management of kidney injuries. J.A.M.A., **154:** 198–202, 1954.
7. Williams, R. D. and Zollinger, R. M. Diagnostic and prognostic factors in abdominal trauma. Am. J. Surg., **97:** 575–581, 1959.

BLUNT ABDOMINAL TRAUMA

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Despite their relative infrequency, the high mortality of abdominal injuries due to blunt trauma requires a re-evaluation of our diagnostic accuracy and methods of management. Although it is estimated that only one in every eighteen thousand to twenty thousand hospital admissions are for visceral damage due to blunt trauma (3), our experience suggests that this figure is low. Auto accidents are accounting for an increasing number of such injuries (2, 7). Since blunt abdominal trauma is more frequent than penetrating injuries in civilian practice (1) and poses the greater diagnostic problem, we have attempted to determine factors which affect diagnostic accuracy and mortality (8). More recently, blunt abdominal injuries have been reviewed and an attempt has been made to evaluate in the laboratory the factors which cause visceral injuries. The findings in 158 patients with blunt abdominal trauma, will be compared with those noted after mechanically induced injuries in dogs.

METHODS AND MATERIAL

Abdominal trauma was produced in 80 mongrel dogs in whom other experimental procedures outside the abdomen had been performed. Thus trauma was used as a method of sacrifice or just prior to termination of an experiment. They were anesthetized with intravenous Nembutal and placed in a stand constructed to maintain a "sitting" position. This allowed the viscera to assume a position similar to those in humans sitting in an automobile. The site, area, and force of trauma to the abdomen were varied. A solid weight, approximately the size of a steering wheel, in comparison with the relative dog size, was used. This weight was dropped, in pendulum fashion, from a measured height, so that energy could be calculated from the measured weight and height. The location of the striking force was also varied in order to determine its effect on the visceral injuries produced.

All animals were examined immediately after trauma for external and internal abdominal injuries. Needle paracenteses were done, at least in all four quadrants, and an attempt was made to correlate the findings with the location and amount of blood, if any, in the peritoneal cavity. The abdomen was widely opened, carefully inspected, and all injuries recorded. The animals were then sacrificed with large injections of Nembutal.

RESULTS

The number of specific organ injuries in the 80 dogs were compared with those

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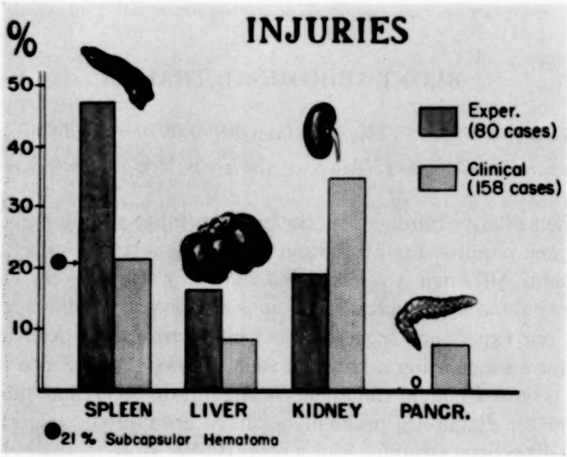


FIG. 1. The percentages of experimentally induced and clinically noted abdominal solid organ injuries are compared. Note that by eliminating splenic subcapsular hematomata the incidence of experimentally induced splenic injury is similar to that in patients.

in 158 patients with blunt abdominal trauma. Splenic injuries were more frequent in dogs. They occurred in 38 (47.5%) of the dogs and only 34 (21.6%) of the patients. Half of these injuries in dogs were subcapsular hematomas, a lesion which would be missed unless exploratory laparotomy was performed in all patients suspected of any abdominal injury. If subcapsular injuries are not considered, the experimental figures are almost identical with our clinical experience (Figure 1). Injury to the liver was also more frequent in dogs. This, too, may be due to the failure to diagnose all hepatic injuries in patients. All of the lacerations in the dogs in these experiments had stopped bleeding by the time of laparotomy.

Renal and pancreatic injuries occurred more frequently in patients. Injuries to the kidney occurred in 34.4% of the patients and only 18.8% of the dogs. This difference is apparently due to two causes. First, hematuria or calyceal distortion as shown by pyelography are considered evidence for renal injury in patients. The experimental injuries were identified by gross examination. Second, the frequency of flank trauma in patients is unknown; however, because of an increase in renal injuries with experimental flank trauma, it must be relatively common in accidents producing blunt trauma. Gross pancreatic injury was not produced in dogs, perhaps because the pancreas and duodenum are not fixed as they are in humans.

Hollow visceral and mesenteric injuries were more frequent in the animals than in patients (Figure 2). All serosal tears of the bowel and mesentery, even when hemorrhage was not great, were recorded in these experiments. Seven of the experimental bladder injuries were confined to the mucosa. These mesenteric and bladder injuries would not have been confirmed in patients in whom symptoms did not warrant surgical exploration. These findings suggest that the varying percentages of abdominal visceral injuries reported clinically may result from differ-

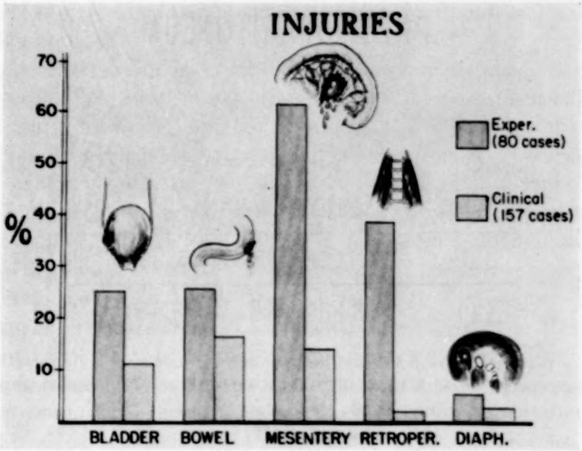


FIG. 2. Note the greater incidence of injury to the bladder, bowel, mesentery, and retroperitoneal area produced experimentally. Many of these injuries were probably not severe enough to warrant laparotomy if present in patients.

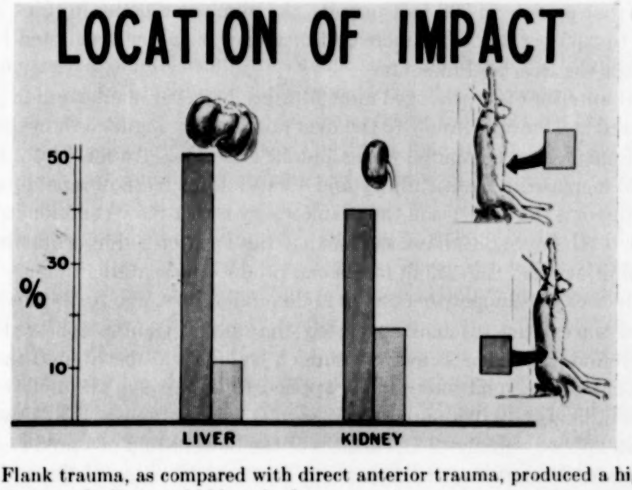
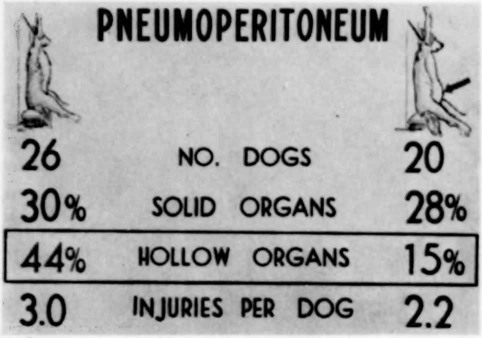


FIG. 3. Flank trauma, as compared with direct anterior trauma, produced a higher incidence of injury to the liver and kidney in dogs.

ences in opinion of the criteria for surgical exploration of the abdomen. Unless the most important criterion for laparotomy is pain, some mesenteric tears will never be diagnosed clinically.

In the first portion of this study, the size of the striking force, location of the force, and its energy were varied to determine their effect. The number of organs injured increased with the size of the striking object. With an object of six square



PNEUMOPERITONEUM

26	NO. DOGS	20
30%	SOLID ORGANS	28%
44%	HOLLOW ORGANS	15%
3.0	INJURIES PER DOG	2.2

FIG. 4. The percentages of solid and hollow organ injuries in 26 dogs without pneumoperitoneum are compared with those of 20 dogs with 100 cc per pound intraperitoneal air. Note that protection was afforded only the hollow organs.

inches, there were 1.66 organ injuries per dog. When the area was increased to 36 square inches with the same energy, the number of organ injuries increased to 2.68 per dog. The type of injury did not vary; however, there was an increase in retroperitoneal tissue damage. As the energy of the abdominal blow increased from 200 foot pounds to 300 foot pounds, the number of organ injuries increased from 1.5 to 2.65 per dog. This increased incidence of injury was noted for all organs except the liver and mesentery.

A direct anterior blow produced more injuries; however, flank trauma produced an increased incidence of injury to the liver and kidney. Figure 3 shows that when flank trauma alone is compared with all blunt abdominal trauma in dogs, there is a five-fold increase in hepatic injury and a two-fold increase in renal injury. This further supports the contention that flank injury is relatively common in accident cases. Thus, these studies have shown that the location is important in hepatic and renal injury and that small forces can produce mesenteric injury.

The effect of pneumoperitoneum on abdominal injury due to trauma was also evaluated since Reed (6) had suggested that blunt trauma followed Pascal's Law. He found that the pressure from sudden trauma was distributed throughout the abdomen with equal forces being applied to all areas of the hollow viscera. The intraluminal and extraluminal pressure increases were equal. Thus, even explosive forces applied equally to all surfaces of the bowel could not produce rupture. Hollow visceral injuries apparently result from the pinching of these viscera between the anterior and posterior abdominal walls or the abdominal wall and the spine, rib cage or pelvis.

With the intraperitoneal injection of 100 cc of air per pound in 20 dogs, there was no difference in the incidence of solid organ injuries in comparison with 26 dogs without pneumoperitoneum (Figure 4). There was a significant decrease in the incidence of intestinal and bladder injuries. The former was noted about two-fifths as often (15% versus 38.5%) and the latter less than one-third as often (15% versus 50%). Thus air in the peritoneal cavity has a definite buffering effect. In addition, rupture of the diaphragm was produced only in those dogs with pneumoperitoneum.

Prior to opening the abdomen, paracenteses were performed. Blood was obtained in over 90% of those animals found to have blood present at the time of intra-abdominal inspection. This compares with a 79% accuracy of needle paracentesis previously reported in patients (8). The experimental accuracy is due to the practice of tapping all four quadrants and, in addition, the flanks when these areas were negative. In five dogs, blood was obtained by flank taps after negative anterior paracenteses. The reverse was also true, since blood was obtained in five anterior taps after negative flank paracenteses.

In an attempt to explain four negative paracenteses, needles were left in place and the abdomen opened. The needle was found to have passed obliquely along the peritoneum without penetrating it. Clinical experience has also shown that a long paracentesis needle can penetrate both anterior and posterior peritoneum and yield retroperitoneal blood. This might be considered a false positive tap. Finally, although paracentesis with a needle has been considered to be potentially dangerous, we have found it difficult to puncture the intestines in dogs even with a sharp needle. The resilience of canine intestines is greater than that of man, however.

DISCUSSION

In a comparison of induced injuries in animals with accidental blunt abdominal trauma in man, several factors must be considered. The maximum iniury in these experiments was only 300 foot pounds or equivalent to 7 miles per hour; however, the potential energies at varying speeds in automobile accidents are much greater. For example, a 150 pound man striking a steering wheel at only 15 miles an hour exerts over 1100 foot pounds of force. It is doubtful that direct forces to the abdomen are often applied in automobile accidents, since other parts of the body usually break the force of impact. Furthermore, except when asleep or under the influence of alcohol, the abdominal musculature is usually not relaxed in a person involved in an accident.

The results of these studies in dogs suggest the need for further evaluation of the causative factors in abdominal trauma. The slight protection of the intestine and bladder by pneumoperitoneum suggests that all abdominal injuries do not entirely follow Pascal's Law, as reported by Reed (6). Solid organs obtained no protection from the buffering effect of intra-peritoneal air. Thus the concussion effect of sudden trauma may be more effective in producing solid organ than hollow visceral injury. However, Pugh (5) found no evidence of solid visceral injury in thirty-five emersion blast injuries. Moritz (4) suggested that post-prandial hyperemia causes an increased susceptibility to injury of the liver. The effect of intestinal distention with air and fluid has not been studied. These factors, plus the failure to find gastric injury in 158 patients and 80 experimental cases of abdominal trauma and the lack of diaphragmatic injury without pneumoperitoneum have not been explained.

SUMMARY

Abdominal injuries mechanically produced in 80 dogs have been compared with similar injuries noted in 158 patients with blunt abdominal trauma. Injuries produced experimentally were found to be related to the size, energy, and location of the striking force. The greater the energy or the larger the striking object the more visceral injuries were induced. Flank trauma produced an increased incidence of hepatic and renal injuries. Only a small force was required to produce mesenteric injury. Subcapsular splenic hematoma and minor mesenteric lacerations were common. If these are eliminated from the total injuries, the incidence of splenic and mesenteric injury would approach that noted in humans, suggesting that minor injuries in patients may be frequently overlooked. It may be that these minor injuries cause the prolonged ileus in patients who do not have diagnostic findings demanding immediate surgical exploration. Needle paracentesis is accurate in determining the presence of intra-peritoneal blood; the needle does not easily penetrate the intestine; and errors result from the failure to perform multiple taps or the oblique passage of the needle without penetration of the peritoneum. Pneumoperitoneum partially protects hollow viscera suggesting the need for further studies of the factors which produce injury to solid and hollow viscera.

REFERENCES

1. Cloutier, L. C. and Zaepfel, F. M. Traumatic rupture of the spleen. Surg., Gynec. & Obst., **107:** 749–752, 1958.
2. Deloyers, L. Nonpenetrating injuries of the abdomen. Acta orthop. belg., **24:** 97, 1958. (Internat. Abstr. Surg., **109:** 266, Sept. 1959)
3. Heaton, L. D. and Glew, D. H., Jr. General considerations in abdominal wounds. S. Clin. North America, pp. 1569–1576, Dec. 1958.
4. Mortiz, A. R. *The Pathology of Trauma*, 2nd ed., p. 245, Lea & Febiger, Philadelphia, 1954.
5. Pugh, H. L. Surgical report on immersion blast injuries. U. S. Naval M. Bull., **41:** 9–12, 1943.
6. Reed, J. V. Relation of trauma to rupture of hollow abdominal viscera. Arch. Surg., **27:** 216–226, 1933.
7. Watkins, G. L. Blunt trauma to the abdomen. A.M.A. Arch. Surg., **80:** 187–191, 1960.
8. Williams, R. D. and Zollinger, R. M. Diagnostic and prognostic factors in abdominal trauma. Am. J. Surg., **97:** 575–578, 1959.

DISCUSSION

Dr. Theodore Drapanas (Buffalo, New York): Dr. Baxter has presented a novel experimental approach to the problem of blunt abdominal injury, and I would like to comment on some aspects of it. I think it is highly significant that needle paracentesis was positive in over 90 per cent of the animals in which the presence of blood was verified at the time of laparotomy.

Dr. Roger Williams, I believe, also reported before this Association in 1958 a 79 per cent accuracy of peritoneal taps performed in patients with blunt abdominal trauma. I am in complete agreement with the recommendations of this simple and safe procedure as a diagnostic tool in trauma. Some physicians, however, continue to deplore its use as a dangerous and ineffective procedure, and a larger number do not know how to do it correctly.

We, too, have performed a large number of taps at our institution in the past ten years, and this has become an almost routine procedure in any patient with suspected abdominal visceral injury.

(Slide) Our statistics are very similar to those presented by Dr. Baxter; that is, an 82 per cent accuracy of peritoneal taps verified by laparotomy with no complications that we have attributed to the procedure.

(Slide) As far as the technique is concerned, we perform four-quadrant taps lateral to the rectus sheath and even bilateral flank taps if indicated in the same patient with a long, blunt 18-gauge spinal needle, and we have had no complications that we feel have been the result of this type of needle aspiration.

We feel that puncture through the rectus sheath, however, should be condemned as a dangerous procedure because of the possibility of lacerating the epigastric vessels, which we have seen result in a rectus sheath hematoma. Furthermore, I think it is apparent that one has a greater chance of penetrating the bowel in the human, because the gas filled loops of bowel tend to rise in a peritoneal cavity which contains blood.

(Slide) This simply shows the technique that we use in lateral flank taps, which are performed midway between the costal margin and the iliac crest.

President Stack: Dr. Baxter, do you have any closing remarks?

Dr. Chadwick F. Baxter (Columbus, Ohio): No. I would like to thank Dr. Drapanas for his discussion.

We agree completely that needle paracentesis is a fairly innocuous procedure and should be done.

INJURIES OF THE ELBOW: A TEN YEAR REVIEW

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From The Combined Fracture Service of The New York Hospital and The Hospital for Special Surgery, New York, New York

This study was undertaken in an effort to evaluate the results of treatment of fractures and dislocations of the elbow seen from 1948 to 1958 by The Combined Fracture Service of The New York Hospital, Cornell Medical Center-The Hospital for Special Surgery. Emphasis was placed on the cases with complications and those with poor results in the hope that their treatment could be improved in the future.

With these objectives in mind 414 injuries of the elbow seen by the fracture service from 1948 to 1958 were reviewed. Elbow injuries accounted for 6.8 per cent of all fractures treated during this period. Table 1 lists the classification system used in the study. Of the 414 patients in the series 45 per cent were hospitalized and 24 per cent were submitted to operative procedures.

The age distribution by decades and the general form of treatment used for each group of injuries are listed in Table 2. Radial head fractures occurred most frequently in the third through the sixth decades and supracondylar fractures were most common in the first two decades. Fractures of the proximal ulna and dislocations showed no significant age distribution. Also there was no statistical difference in the sex distribution.

Seventy-six per cent of the patients were followed from six months to eight years after their injuries. The average length of follow-up was four years. The final results were evaluated according to the Massachusetts General Hospital Grading System.

SUPRACONDYLAR FRACTURES

Children

Forty-six children were treated for supracondylar fractures. Of these, 39 were treated by closed reduction and immobilization for three to four weeks, four by skeletal traction, three by Dunlop's skin traction, and one by open reduction.

Of the 39 treated by closed reduction and immobilization, 35 did very well. Four patients developed 5 to 10 degrees cubitus varus with 10 to 15 degrees loss of flexion. These four patients had posteriorly displaced supracondylar fractures with angulation of the distal fragment. On the post-reduction roentgenograms taken in plaster the displacement was thought to have been corrected. When the plaster was removed the rotation of the fragments had not been perfectly reduced and the fractures healed with some deformity of the elbow. These cases demonstrate the difficulty that may be encountered in obtaining true anterior-posterior

Read before the Twentieth Annual Session of The American Association for the Surgery of Trauma, Coronado, California, October 5–7, 1960.

TABLE 1

Classification of Elbow Injuries

- Distal humerus
  - Supracondylar
  - Transcondylar, dicondylar, intercondylar
  - Lateral condyle with or without capitellum
  - Medial condyle
  - Trochlea
- Proximal radius
  - Neck
  - Head
- Proximal ulna
  - Olecranon
  - Coronoid
  - Proximal one third of shaft
- Dislocations
  - Simple
    - Anterior
    - Posterior
    - Lateral
    - Radial head (pulled elbow)
  - Fracture-dislocations
    - Anterior
      - Fracture olecranon
      - Fracture ulna
      - Monteggia
    - Posterior
      - Fracture coronoid
      - Fracture shaft of ulna
      - Fracture radial head
      - Monteggia
    - Lateral
      - Fracture medial epicondyle of humerus
      - Fracture lateral condyle of humerus

roentgenograms of the flexed elbow. If angulation or rotation is left uncorrected it will lead to limitation of motion and deformity of the elbow. Figure 1 shows a displaced supracondylar fracture in a 12-year-old girl. The rotational deformity was recognized and easily corrected by internal rotation of the distal fragment. She has no deformity and no loss of motion. The small spur present anteriorly will disappear with further growth. Because of failure to recognize and correct angulation or rotation of the fragments, four of 39 children with supracondylar fractures treated by closed reduction and immobilization developed deformities and limitations of motion.

Skeletal traction was used to treat five children with comminuted or displaced supracondylar fractures that could not be reduced or held in plaster. The traction was maintained for ten to fourteen days, followed by immobilization in plaster for three to four weeks. Figure 2 shows a patient in skeletal traction with the wire placed through the proximal shaft of the ulna and with countertraction exerted

TABLE 2

Age Distribution and Treatment

Age	Radial Head			Distal Humerus			Proximal Ulna			Dislocations		
	All	Nonop	Op	All	Nonop	Op	All	Nonop	Op	All	Nonop	Op
0–10	10	9	1	61	57	4	10	10	0	8	8	0
11–20	11	9	2	25	19	6	6	5	1	6	6	0
21–30	25	23	2	11	9	2	8	7	1	9	7	2
31–40	27	22	5	5	3	2	11	5	6	9	5	4
41–50	31	25	6	8	7	1	10	7	3	9	8	1
51–60	21	16	5	15	12	3	12	5	7	10	6	4
61–70	8	3	5	9	8	1	15	8	7	7	4	3
71–80	4	2	2	2	1	1	8	2	6	0	0	0
81–90	1	0	1	2	2	0	0	0	0	0	0	0

by a sling about the upper arm. The forearm is supported by a sling which should not allow the wrist and hand to be unsupported.

Two children with supracondylar fractures with marked edema about the elbow were placed in Dunlop's traction for three to five days until the edema began to subside. They were then immobilized in plaster for three to four weeks.

One of the patients treated in Dunlop's traction was only able to flex to 65 degrees when seen five years post-injury. She was a six-year-old girl with a supracondylar fracture which was manipulated and immobilized in plaster for two days. Then because of redisplacement of the fragments she was placed in skin traction for five days. After this she was again immobilized in plaster for three weeks. While in traction the fracture was in good position; however, it healed with posterior angulation of the distal fragment. If the traction had been maintained for a longer period the fragments might not have slipped.

The five patients who were kept in skeletal traction for 10 to 14 days had no loss of position when the traction was discontinued. All five of these patients have excellent function with no deformities. No complications were encountered that were due to the traction.

Only one patient, a seven-year-old boy with an unstable, anteriorly displaced, supracondylar fracture, underwent open reduction and internal fixation with two crossed Kirschner wires. He was immobilized in a posterior splint at 135 degrees for three weeks. On follow-up examination seven years later there was no deformity and a full range of motion.

Evaluation of the end-results of treatment of supracondylar fractures in children leads us to believe that wider use of skeletal traction may prevent the ten per cent incidence of anatomic and functional deformities encountered in the cases treated by plaster immobilization in our series. There were no deformities or complications in the few cases treated by traction. Only one patient was submitted to open reduction and the result was excellent.

Adults

During the ten-year period under consideration 37 supracondylar fractures were treated in adults. Five of these were open fractures.

Eighteen of the fractures were displaced or comminuted. These were manipulated and immobilized in plaster for four to six weeks. In fourteen of these patients an excellent result was obtained. Four of them have limitation of motion and deformities due to failure to correct rotation or displacement of the fragments. In two of these four patients the medial condyle is displaced distally. One of them can extend to 135 degrees and flex to 85 degrees while the other one can extend to 135 degrees and flex to 50 degrees. The fractures in the other two patients healed with posterior angulation of the distal fragment. One of them can extend to 165 degrees and flex to 90 degrees and the other can extend to 170 degrees and flex to 60 degrees.

Four patients with undisplaced supracondylar fractures were immobilized for only two to three weeks. In all of them an excellent result was obtained.

Skeletal traction through the ulna was used for 12 patients with comminuted or markedly displaced supracondylar fractures. Eight of these patients, including four with open fractures, were kept in traction for two to four weeks. This was followed by plaster immobilization for another two to three weeks. Two of the 12 were removed from the traction during the first week because of infection at the pin site and two others because of accompanying medical diseases.

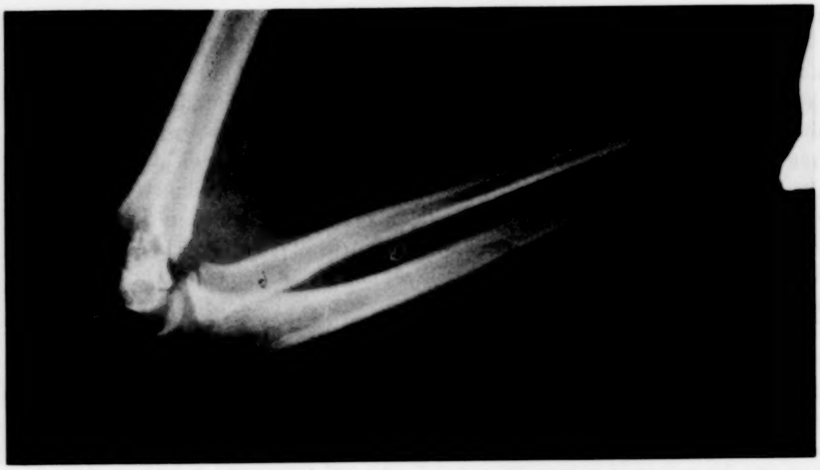
In seven of the eight patients kept in traction for two to four weeks, an excellent anatomic and functional result was obtained. The other patient in this group healed with a ten degree cubitus valgus and could only extend to 165 degrees and flex to 55 degrees.

Two patients developed infection at the pin site during the first week of treatment in spite of the fact that all of the Kirschner wires were inserted in the operating room. The infections healed promptly with removal of the wires, local drainage, systemic antibiotics, and immobilization in plaster. However, both have marked limitation of motion with extension to only 120 degrees and flexion to 90 degrees.

Traction was discontinued during the first week in two other patients. One had developed an acute psychosis and the other had delirium tremens. The patient with delirium tremens died of hepatic failure 12 weeks post-injury at which time he could extend to 120 degrees and flex to only 110 degrees. The other, when seen two years after his injury, could extend to 100 degrees and flex to 90 degrees.

The infection adjacent to the elbow was undoubtedly the major factor in causing the poor result in two of these patients. In addition, the early discontinuance of the traction resulted in loss of position of the fragments, late deformities and limitation of motion. These cases emphasize the importance of continuing traction until the fracture is stable. Also every effort must be taken to prevent infection at the site of skeletal traction wires.

Two patients with displaced supracondylar fractures (one an open fracture)



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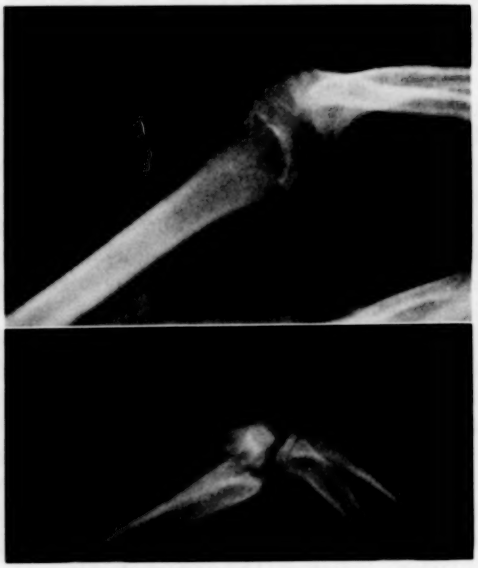

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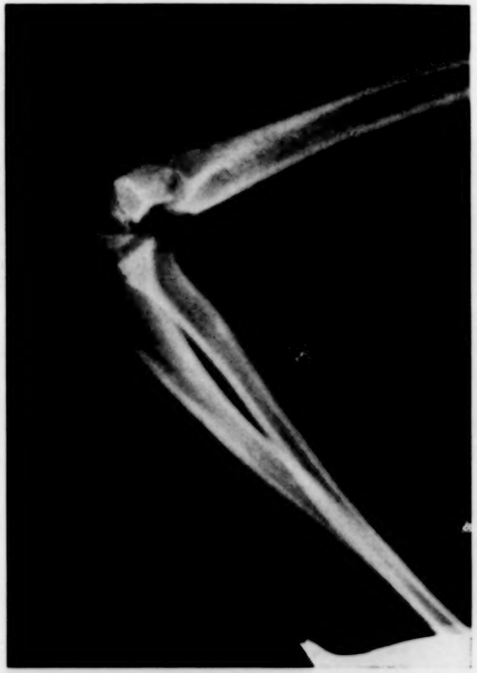

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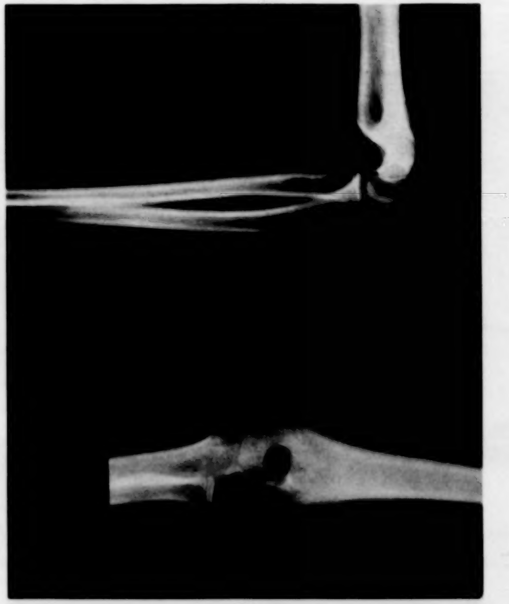

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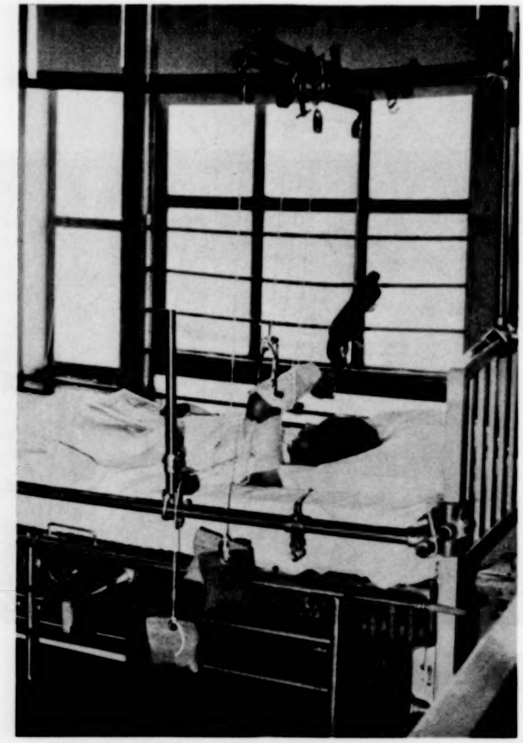
FIG. 1. a. Displaced supracondylar fracture in a twelve-year-old girl. b. Incomplete reduction following traction and flexion of the elbow. Note "fishtail deformity" due to external rotation of the distal fragment. c. Rotational deformity corrected by internal rotation of the distal fragment. d. Eighteen months post-fracture with full range of painless motion.



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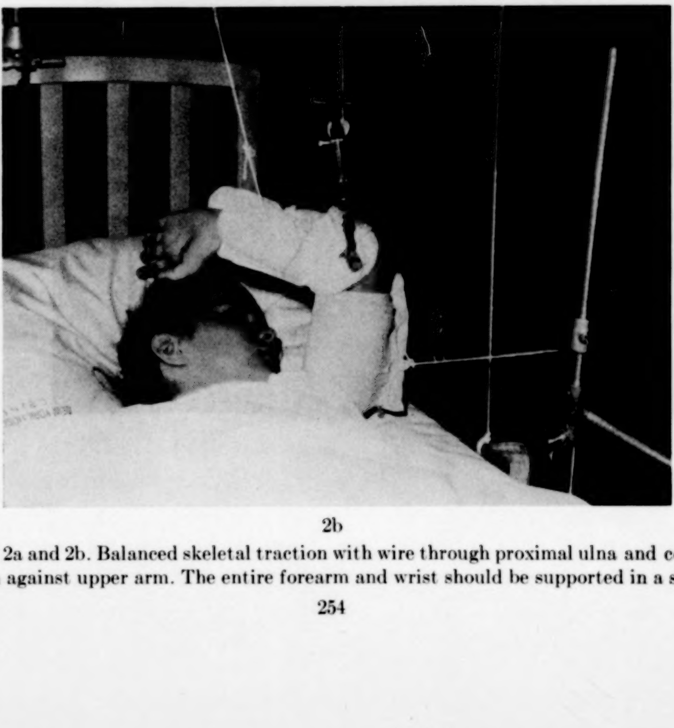


2b

FIGS. 2a and 2b. Balanced skeletal traction with wire through proximal ulna and countertraction against upper arm. The entire forearm and wrist should be supported in a sling.

underwent open reduction and internal fixation with two screws. They were immobilized for two weeks and in both the results were good. It is our feeling that internal fixation may be the treatment of choice in certain selected cases among the elderly in order to hasten early ambulation of the patient and active motion of the elbow.

One patient with a comminuted supracondylar fracture underwent open reduction and plaster immobilization without internal fixation because of marked comminution of the fracture. The plaster was removed after only three weeks. Some time during the following two weeks the lateral condyle displaced distally. He now has cubitus varus of five degrees. The period of immobilization should have been longer in order to prevent the displacement of the condyle. Also it might have been better to have treated him in traction.

In adults, as in children, the best results were seen in the group treated by skeletal traction. However, there were two complications directly due to the traction. These were the two infected pin sites. The worst results were in the patients whose traction was discontinued too early. The two patients who underwent internal fixation of their fractures did very well.

FRACTURES OF THE MEDIAL EPICONDYLE

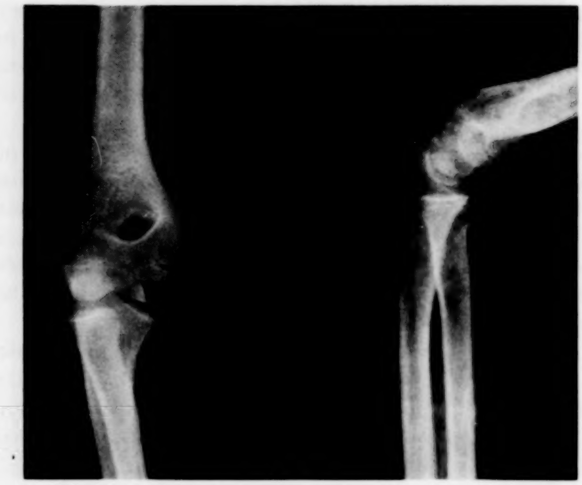
Children

In the series there were 19 children with fractures of the medial epicondyle. Fifteen were treated by closed reduction and immobilization. Those with minimal epiphyseal separation or displacement of the fragments were immobilized for three to four weeks. The children with chip fractures or undisplaced linear fractures were immobilized for only five to ten days. Results were excellent in 14 of these 15. The fracture in the other patient healed with the medial epicondyle displaced distally. This patient has no functional defect but five years post-fracture a definite deformity can be seen in the X-rays and on inspection of the elbow. Four children with fractures of the medial epicondyle required open reduction because of displacement of the epicondyle into the joint. (See figure 3.) In this group catgut suture of the epicondyle was used in three and in one the epicondyle was held with a screw. Two of these four children underwent primary transplantation of the ulnar nerve. All four in this group have a full range of motion and no deformities despite the fact that two of them have a fibrous union of the fracture.

Adults

There were eight adults with fractures of the medial epicondyle. Seven were undisplaced avulsion fractures which were immobilized for two to three weeks with excellent end-results.

One of these eight patients was noted to have an incomplete ulnar nerve palsy one week post-fracture. The nerve was explored and transplanted four weeks later. At that time the fracture was undisplaced and the nerve was grossly normal. There has been full return of function of the nerve and no deformity of the elbow.



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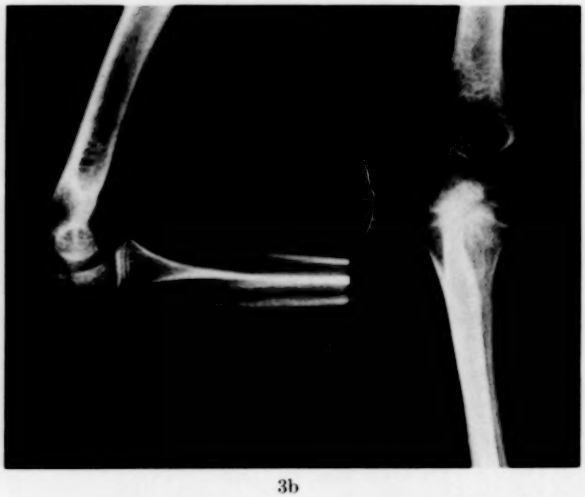


3b

FIG. 3. a. Fracture of the medial epicondyle with displacement of the fragment into the joint. b. Two months after open reduction and catgut suture of the fragment.

FRACTURES OF THE LATERAL CONDYLE

Children

Eighteen fractures of the lateral condyle were seen in children. Thirteen of the 18 were undisplaced fractures and were immobilized for only two to three weeks. The ten who were seen in follow-up showed good results.

Because of displacement or rotation of the condyle, five children underwent open reduction. In four there was simple suture of the fragment (fig. 4), while in one there was internal fixation with two threaded Kirschner wires. Immobilization in plaster was continued for three to five weeks postoperatively.

When seen in follow-up clinic there were no anatomic or functional deformities in four of this group. One ten-year-old boy who had undergone open reduction and catgut suture of the condyle had developed a five degree cubitus valgus deformity without limitation of motion when seen six years after sustaining his fracture.

No tardy ulnar nerve palsies have been reported in any of the patients in our series. Accurate anatomic reductions of the lateral condyle and minimal trauma to the distal lateral humeral epiphyseal plate are necessary to prevent late deformities and tardy ulnar nerve palsies.

Adults

Only eight fractures of the lateral condyle were treated in adults. Seven were avulsion fractures which required only two to three weeks of immobilization. One underwent internal fixation with a screw because of displacement and rotation of the fragment. The results were good in all of these patients.

FRACTURES OF THE CAPITELLUM

Children

Only five fractures of the capitellum were seen in children. Two with undisplaced fractures were immobilized for three weeks and end-results in both of them were excellent. Three with displaced fractures required operative replacement of the capitellum. Two of these three were available for follow-up evaluation and there were no deformities, complaints of pain, or limitations of motion in either patient.

Adults

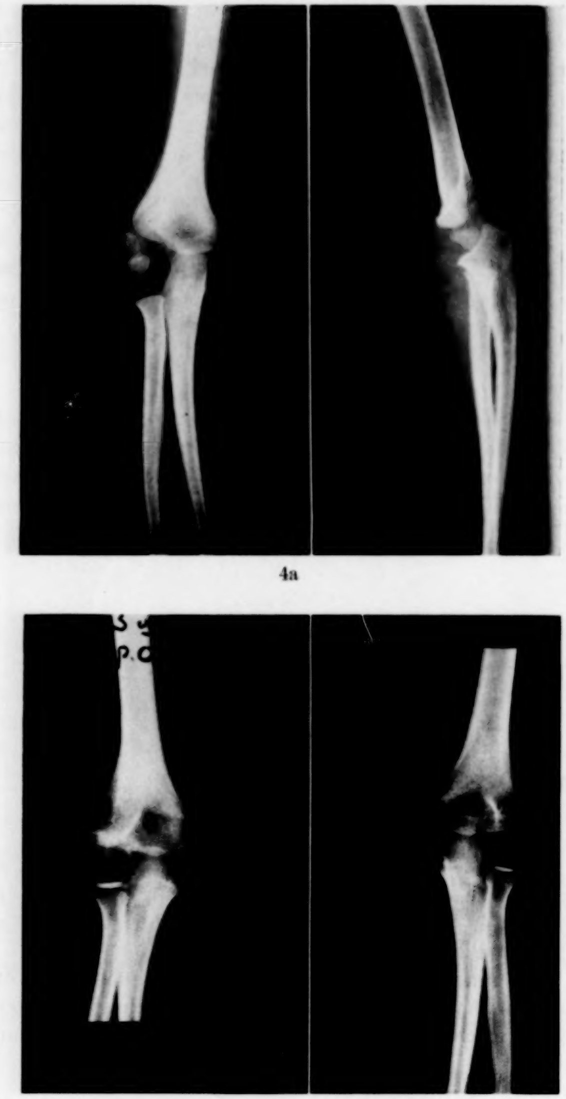
Four fractures of the capitellum were treated in adults. One with a small chip fracture required no treatment. Three patients underwent operative intervention. In two of these three, the capitellar fragment was excised and in the third the fragment was reduced and sutured in place.

There was a full range of motion and no history of subluxation of the elbow when the two whose capitellum was excised were seen three years post-fracture. The patient who underwent operative replacement of the capitellum has been lost to follow-up.

FRACTURES OF THE HEAD AND NECK OF THE RADIUS

Children

Eighteen fractures of the radial head or neck were seen in children. These fractures were manipulated only if the head was displaced more than 45 degrees.



4a

4b

Fig. 4. a. Fracture of the lateral condyle with distal displacement of the fragment in a four-year-old boy. b. Three years after open reduction and suture of the condyle anatomic and functional results are excellent.

Open reduction was necessary only if closed reduction failed or if the head were off the shaft.

Nine children in whom the displacement of the head was less than 45 degrees or who had comminuted fractures were immobilized in plaster with the forearm in moderate flexion and almost full supination for two to three weeks. They were then allowed limited motion in a sling for another week. Four others with fissure fractures of the radial head required rest in a sling until the pain and edema subsided. Three of the 13 treated by immobilization required early aspiration of the joint. Aspiration of the hemarthrosis led to early relief of pain and return of function. No deformities or loss of motion were noted in the nine children seen in follow-up.

Four children required manipulation of their fractures because displacement of the head of the radius exceeded 45 degrees. They were then immobilized for three to four weeks. In three there is no deformity or loss of function. One, however, developed a "mushroom" type of deformity of the radial head and can extend to only 165 degrees, flex to 60 degrees, supinate to 60 degrees, and pronate 30 degrees.

One eight-year-old boy underwent open reduction of a radial head fracture which was displaced off of the neck of the radius. (See figure 5) Following reduction, he was immobilized in a posterior splint for one week and in a sling for an additional two weeks. Six weeks later the fracture was still reduced but the fracture line was much more evident. In spite of an extra six weeks of immobilization, the fracture went on to nonunion. Nine years after fracture there was an anterior-medial displacement of the radial head with a five degree increase in the carrying angle. He was able to supinate 30 degrees, pronate 60 degrees, flex to 80 degrees, and extend to 160 degrees.

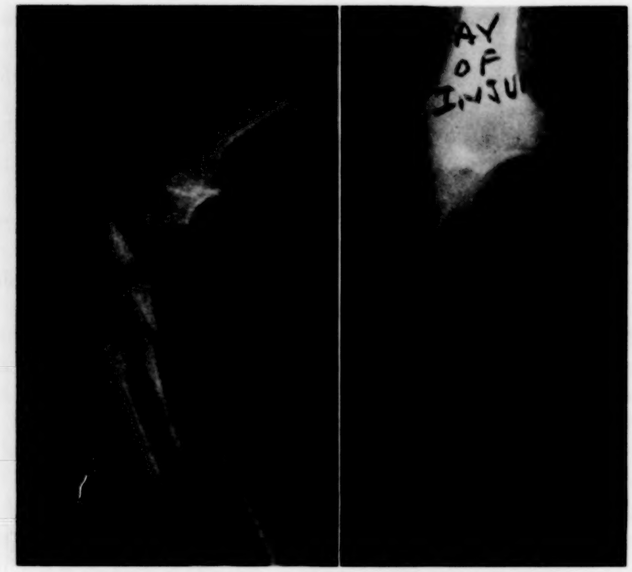
Refracture of a healed undisplaced fracture of the neck of the radius was seen in a 12-year-old boy four months after the original fracture. The refracture healed with no deformity.

Adults

There were 134 fractures of the head and neck of the radius in adults. Fourteen of these fractures were associated with dislocations of the elbow.

If there were no displacement of the fracture, if it were slightly displaced, or if there were minimal comminution, the elbow was immobilized for ten to fourteen days in a posterior splint. In this group there were 93 patients, including 17 who required aspiration of 10 to 15 cc. of blood from the joint. Sixty-three of this group were seen in follow-up and in sixty-one of these motion was excellent and there were no deformities.

After simple immobilization of an undisplaced impacted fracture of the neck of the radius, one 37-year-old lady can extend to only 155 degrees and supinate to 80 degrees despite healing of the fracture in satisfactory alignment. One 49-year-old lady developed myositis ossificans following three weeks' immobilization of an undisplaced marginal fracture of the lateral one-third of the radial head.



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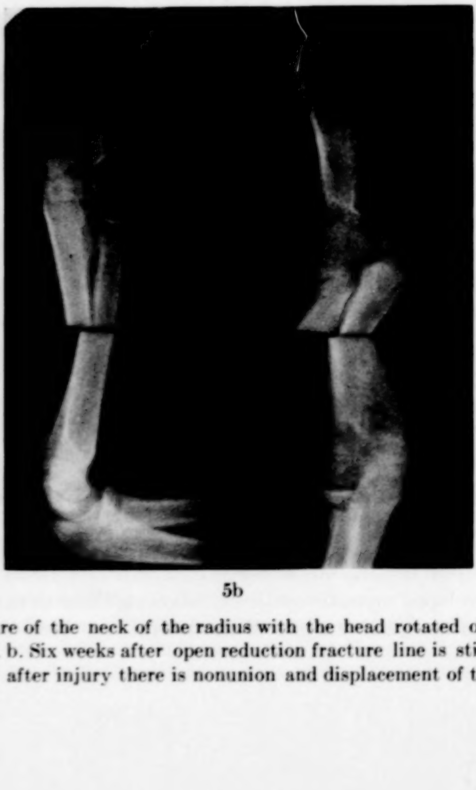

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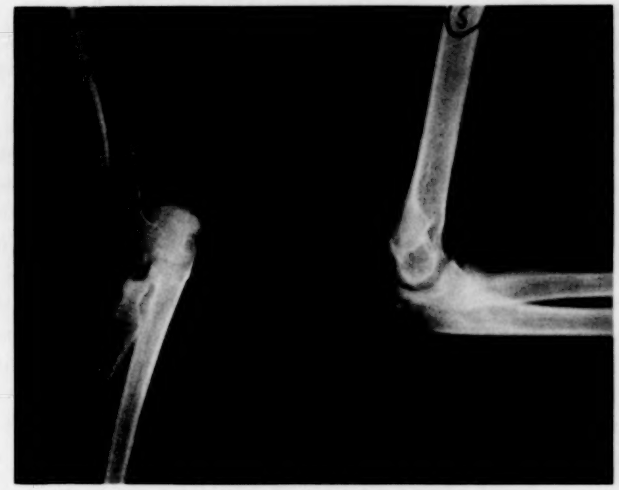
Fig. 5. a. Fracture of the neck of the radius with the head rotated off the shaft in an eight year old boy. b. Six weeks after open reduction fracture line is still evident. c. One year. d. Five years after injury there is nonunion and displacement of the radial head.



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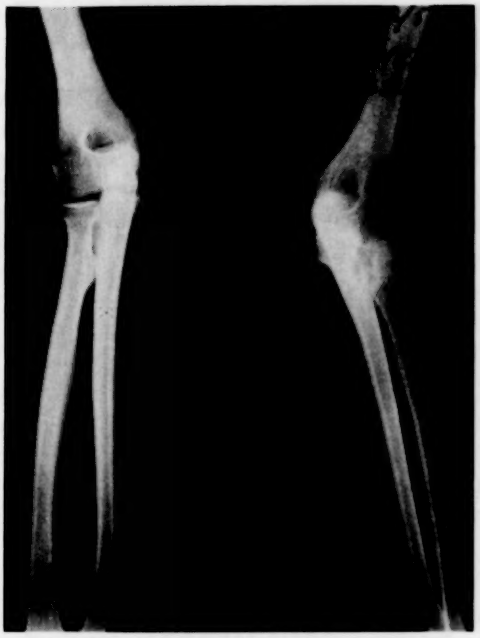


5d

Two months after injury she could extend to 150 degrees and flex to 120 degrees and there was an increasing soft tissue calcification anterior to the elbow. The calcification increased in spite of six extra weeks of immobilization. At the one-

and four-year follow-up visits the calcification was seen to be stable and she could extend to 140 degrees and flex to only 120 degrees. She refused further treatment at each visit even though she might have benefited from excision of the calcified mass after it stabilized.

Thirty-eight patients underwent excision of the radial head for comminuted fractures of the radial head or displaced fractures of the head or neck of the radius. Eleven patients in this group had associated dislocations of the elbow. Thirty of the patients undergoing excision of the radial head were operated upon during the first three days after injury. The remaining eight were not operated upon for six to nine days after they were injured. No complications or poor results were seen in the group having the delayed surgery, while four of the other group have limitation of motion. Following excision of the radial head those patients without subluxation of the elbow were immobilized in a posterior splint for two to seven days, while those with accompanying dislocations were immobilized for three weeks.

Thirty-three of the 38 were available for follow-up evaluation. In 28 there were no anatomic or functional deformities. Four lost 15 to 20 degrees of supination and 10 to 15 degrees of extension. One could extend to 160 degrees, supinate to 85 degrees, and pronate to 70 degrees.

One patient complained of persistent pain in the wrist. There may have been subluxation of the distal radio-ulnar joint in this case, although there was no evidence of this injury on admission. There was one patient with a transient posterior interosseous nerve palsy following excision of the radial head. In this patient the incision was placed too far anteriorally and the nerve was traumatized on reflecting the supinator muscle. The only other complication was a non-fatal pulmonary embolus on the tenth postoperative day in an 82-year-old lady.

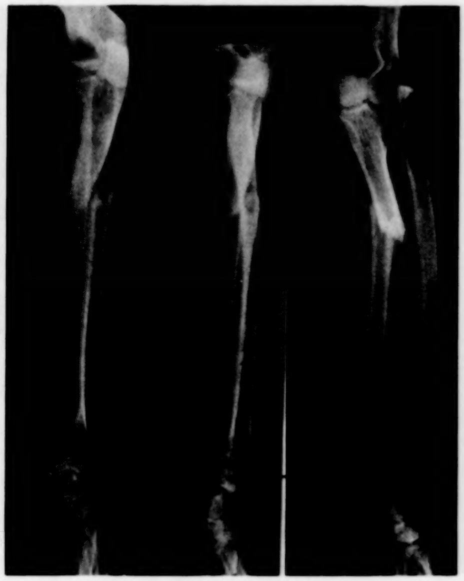
FRACTURES OF THE OLECRANON

Children

Thirteen fractures of the olecranon were seen in children. Those with displacement of the olecranon were manipulated and immobilized in plaster for three to four weeks. Patients with chip fractures or incomplete linear fractures were allowed early active motion. Ten of the 13 children were seen in follow-up and in all of them results were excellent.

Adults

Fifty-nine olecranon fractures were treated in adults. Fourteen patients with undisplaced fractures were immobilized in mid position for four to five weeks. Three of this group required aspiration of an associated hemarthrosis of the elbow. Eight patients with chip fractures were allowed early motion. The end result obtained in 20 of the 22 patients treated by closed methods was very good.



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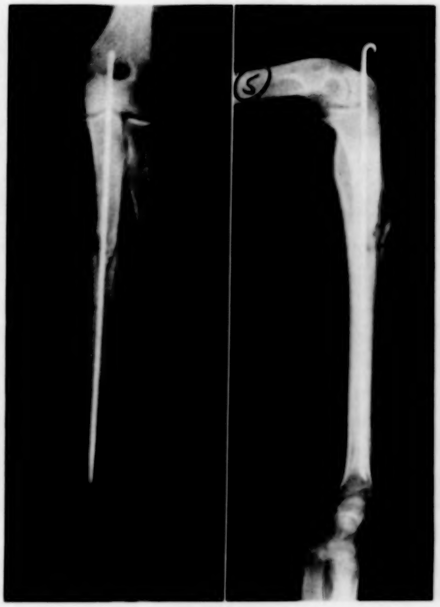

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FIG. 6. a. Monteggia fracture in a 36-year-old man. b. The radial head dislocation has been reduced and internal fixation of the ulnar fracture accomplished with a Rush pin. c. Seven months after fracture there is no limitation of function (see next page).

6c

Operative intervention was necessary in 37 patients with fractures of the olecranon because of displacement or comminution of the fractures. Open reduction and suture of the fragments with stainless steel wire was carried out on 6 patients and internal fixation with screws was performed on 18. Following internal fixation immobilization was continued for one to three weeks.

In two patients who were allowed motion after only ten days the wires broke. These two patients required six weeks of immobilization in plaster following the breaking of the wires. Both fractures healed with no deformity and only five to ten degrees limitation of extension. However, convalescence was prolonged because of the long period of immobilization required to achieve healing. In two patients the screw pulled out following fixation with three inch screws. These patients had been allowed motion after two weeks in plaster. The screws were seen to be loose two weeks after the plaster was removed. Both of these patients underwent removal of the screws and secondary excision of the olecranon. As a result of these experiences, it is now felt that the five to seven inch malleable olecranon screw is the most satisfactory form of internal fixation for displaced olecranon fractures.

Thirteen patients with displaced or comminuted olecranon fractures underwent excision of the olecranon and repair of the triceps expansion. Following excision of the olecranon, the patients were immobilized for only one to two weeks. As much as 50 per cent of the olecranon may be excised without loss of motion, weakness of the elbow, or danger of subluxation. No complications were seen in the 13 patients who underwent primary excision of the olecranon.

FRACTURES OF THE CORONOID

Two coronoid fractures were seen in adults. Both were chip fractures that required rest in a sling until the pain subsided. Both have perfect function. In addition seven chipped coronoids were seen in association with radial head fractures.

MONTEGGIA FRACTURES

Six Monteggia fractures have been treated in adults over the ten-year study period. Four underwent open reduction of the radial head dislocation and internal fixation of the ulnar shaft fracture with an intramedullary rod. (See figure 6.) The other two underwent excision of the radial head because of marked comminution of the head. Postoperatively they were all immobilized in posterior splints for two to three weeks and then allowed guarded active motion.

There was no limitation of motion in three of the four patients in whom the radial head was not excised. Despite excellent healing of the ulnar fracture and reduction of the radial head the fourth patient in this group can extend to only 145 degrees, flex to 60 degrees, pronate 0 degrees, and supinate 30 degrees.

The ulnar fracture healed well in the two patients who underwent excision of the radial head. However, both of these patients, who were over 80 years old,

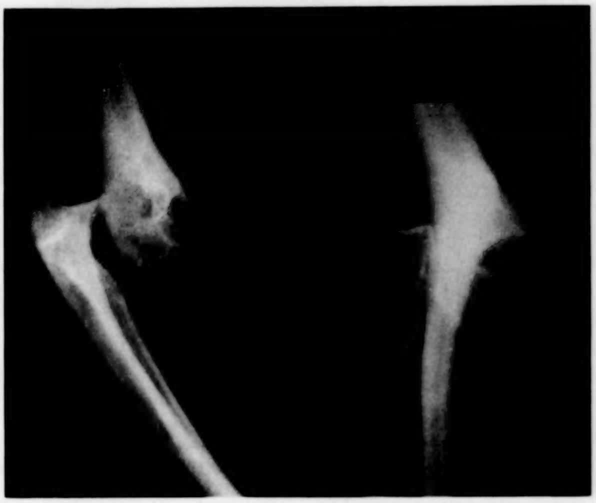

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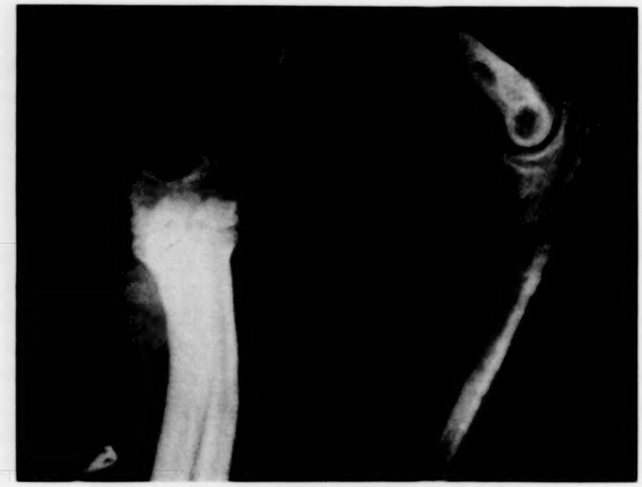
FIG. 7. a. Posterior dislocation of elbow in a 40 year old man with syringomyelia. b. Post-reduction roentgenogram. c. Five months after injury, Charcot joint and myositis ossificans are present but there is good function and no pain (see next page).



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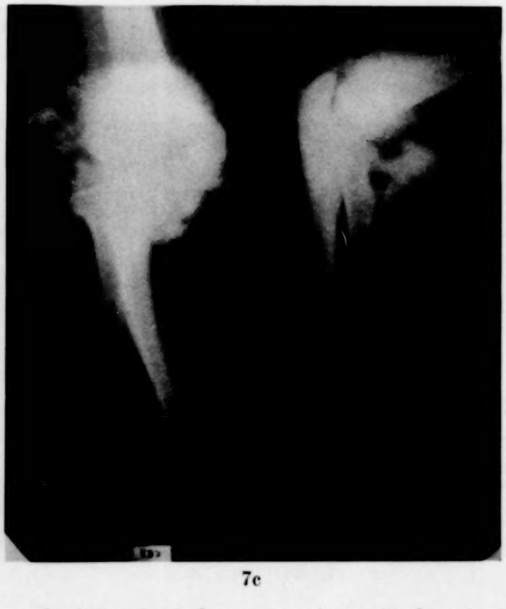

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could extend to only 140 to 150 degrees, supinate 10 degrees, and pronate 15 degrees when seen two years after injury.

DISLOCATIONS OF THE ELBOW

Children

Four posterior-lateral dislocations of the elbow were seen in children. They were reduced by manual traction and then immobilized for two to three weeks.

TABLE 3

Fractures Associated with Dislocations

Dislocation	Rad. Head	Coronoid	Med. Epicondyle	Lat. Condyle	Capitellum
Anterior	1	—	—	—	—
Posterior	12	3	3	2	—
Lateral	1	1	—	—	1
Total	14	4	3	2	1

Following closed reduction of the dislocation, one child required open reduction and suture of an associated fracture of the medial epicondyle. None of these children developed deformities or loss of motion.

Adults

Twenty-four simple dislocations and 23 fracture-dislocations were seen in adults. All of the simple dislocations were posterior or posterior-lateral. These dislocations were reduced with manual traction and then immobilized in posterior splints with the elbow acutely flexed for one to three weeks.

Four patients in this group developed soft tissue calcifications anterior to the elbow. There was spontaneous resorption of the calcium in two of them with no resulting disability. In spite of ten weeks immobilization, there was increasing calcification in one patient. He was lost to follow-up after six months at which time he could extend to only 125 degrees and flex to 100 degrees.

The fourth patient in this group developed a Charcot joint plus myositis ossificans. His roentgenograms are shown in figure 7. He was a 40-year-old man with syringomyelia who had had only one documented posterior dislocation of the elbow. Following reduction of the dislocation and immobilization for two weeks he developed marked soft tissue calcifications and a Charcot joint. Despite this he is now able to extend to 170 degrees, flex to 60 degrees, pronate 45 degrees, and supinate 30 degrees.

Table 3 presents a list of fractures that were associated with dislocations of the elbow. No anterior or lateral dislocations were seen without an accompanying fracture. Therefore, any patient with such a dislocation must be carefully studied for a possible associated fracture.

Eleven of fourteen patients with radial head fractures associated with dislocations underwent excision of the radial head. The indications for excision of the radial head are the same as if there were no dislocation. The only difference in treatment was that they were immobilized with the elbow flexed for three to four weeks. Two of the patients redislocated the elbow during the first ten days while still in plaster. Both were only flexed to only 110 degrees postoperatively because of marked edema about the elbow. This undoubtedly contributed to the redislocation. Following secondary reduction they were flexed to more than 90 degrees and have had no further difficulty.

SUMMARY

1. The treatment of 414 patients with fractures and dislocations of the elbow over a ten-year period is reviewed and evaluated.
2. No cases of Volkmann's ischemic paralysis were encountered in the series.
3. Only two cases of myositis ossificans developed; one followed an undisplaced fracture of the radial head and the other a dislocation of the elbow.
4. Of 39 cases with supracondylar fractures treated by closed reduction and plaster immobilization, four developed deformities as a result of unrecognized displacement.
5. Infection of traction wire sites in the olecranon in two cases resulted in serious disability.
6. The results of eight radial neck fractures in adults operated upon late (six to nine days) were as good as results following early operation.

Discussion of this paper is included with that of the following paper by Dr. Wade and Dr. Batdorf.

SUPRACONDYLAR FRACTURES OF THE HUMERUS: A TWELVE YEAR REVIEW WITH FOLLOW-UP

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AND

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The purpose of this report is to evaluate our experience with supracondylar and transcondylar fractures of the humerus. Discussion will be limited to those fractures occurring in the area bounded by the beginning of flare of the humeral shaft above, and the condyles below. Fractures of the epicondyles are not included. The age distribution chart indicates the vast majority occurred in the first decade and a half. The results obtained will be lasting reminders (Table I).

Fractures in this area when grossly displaced represent a hazard for the patient and a challenge to the surgeon. The risk of vascular impairment must constantly be kept in mind. The obstructed brachial artery and superficial and deep veins are illustrated in Figure I. The deformities of this injury can be hideous and crippling, the worst of which is a Volkmann's contracture. One need experience but one case of Volkmann's ischemic contracture to develop an abiding respect for this fracture.

In the management of a grossly displaced supracondylar fracture of the humerus, the surgeon frequently encounters what McLaughlin aptly terms the "supracondylar dilemma". The pulse obliterates when enough flexion of the elbow is obtained to maintain reduction. The fracture distracts when the arm is extended to the point of adequate pulsatile circulation.

In reviewing one hundred and forty-five cases over a twelve year period at one hospital, it was found that this "dilemma" was met in varying degrees in sixty instances (forty-one per cent).

This review is to determine the quality of care. It is practical to classify the results as good, fair, or poor. A good result is one in which normal function and appearance is obtained. Fair results are those in which any detectable alteration exists in function or appearance though the extremity remains satisfactory for use. A poor result is one in which both appearance and function are altered to such a degree that the patient experiences limitation. It was possible to evaluate forty per cent of these patients on a personal follow-up basis.

Eighty-five cases managed successfully by a single manipulation and plaster fixation represented fifty-nine per cent of the series and are listed in Table II. It is interesting to note that of the thirty-two of these cases in which follow-up

Read before the Twentieth Annual Session of The American Association for the Surgery of Trauma, Coronado, California, October 5-7, 1960.

TABLE I

Age Distribution

0–10	98	61–70	3
11–20	19	71–80	4
21–30	7	81–90	4
31–40	5	91–100	1
41–50	4		

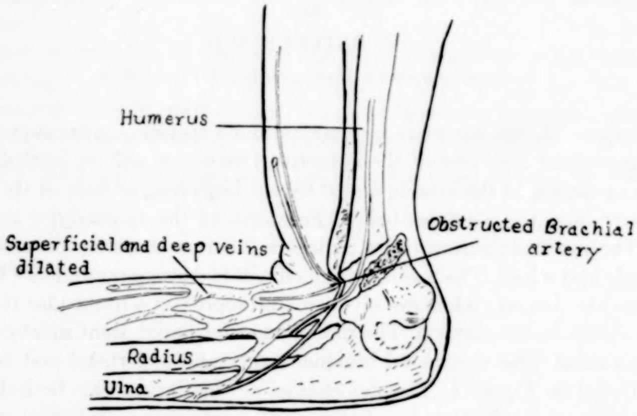
Humerus
Obstructed Brachial artery
Superficial and deep veins dilated
Radius
Ulna

FIG. 1. Relationship of vessels to fracture. Note the obstruction of brachial artery and veins as they cross the fracture site.

was available, there were four classified as poor and nine fair. This serves to emphasize the inherent dangers in this injury regardless of the apparent simplicity initially.

The remainder are those with significant displacement and presenting problems in reduction, vascular impairment, and stability. There are sixty such "problem cases." They have been divided into groups according to the type of management selected by the attending physician.

Table II lists the cases in which multiple manipulations were done to obtain reduction. No traction was used. In some instances as many as four manipulations were attempted. The results are uniformly bad in this group.

Table III includes thirty-one cases in which olecranon traction was used initially with simultaneous manipulation. A forty-five per cent follow-up is available for study. These fractures, by comparison, were equally as severe as those in Table II. There was one poor result.

Even more significant, in Table III, is the group in which multiple manipulations were used (as many as three times) with olecranon traction finally being utilized. There were no poor results.

Table IV includes all cases in which open reduction was used. These were severe fractures, mainly in adults. Two were injuries resulting from the elbow out the car window. Four were the result of gunshot wounds. Functional limitations resulting from these injuries are inevitable.

TABLE II

Manipulation

Single Manipulation With Plaster Fixation, Total Cases: 85 Results		Multiple Manipulations Without Traction, Total Cases: 8 Results	
Good:	59%	Good:	33%
Fair:	28%	Fair:	—
Poor:	13%	Poor:	67%

TABLE III

Olecranon Traction

Initial Olecranon Traction With or Without Simultaneous Manipulation, Total Cases: 31 Results		Multiple Manipulations With Delayed Olecranon Traction, Total Cases: 9 Results	
Good:	57%	Good:	75%
Fair:	36%	Fair:	25%
Poor:	7%	Poor:	—

TABLE IV

Open Reduction

Total Cases: 10 Results	
Good:	40%
Fair:	20%
Poor:	40%

The experience reported above, in the author's opinion, definitely indicates the unquestioned value of olecranon traction in selected cases of supracondylar fracture of the elbow.

Skeletal traction through the olecranon has been used by surgeons associated with the Section for the Surgery of Trauma at Hurley Hospital for twenty years. Since its inception, we experienced no instances of ischemic contracture. In the present series, fasciotomy for evacuation of hematomata was necessary in three instances.

In reviewing the literature, there does not appear to be universal acceptance of this method. One author flatly states this form of management is "unwise, unnecessary, and uncomfortable." Our experience denies this statement in all three parts. Olecranon traction, as illustrated in Figure II, may be recommended as having these advantages:

1) Promotion of dependency.
2) Availability for inspection of pulse, correction of deformity, and X-ray control.
3) Growth centers are protected.
4) Reduction is accomplished physiologically by traction through muscles and ligaments.

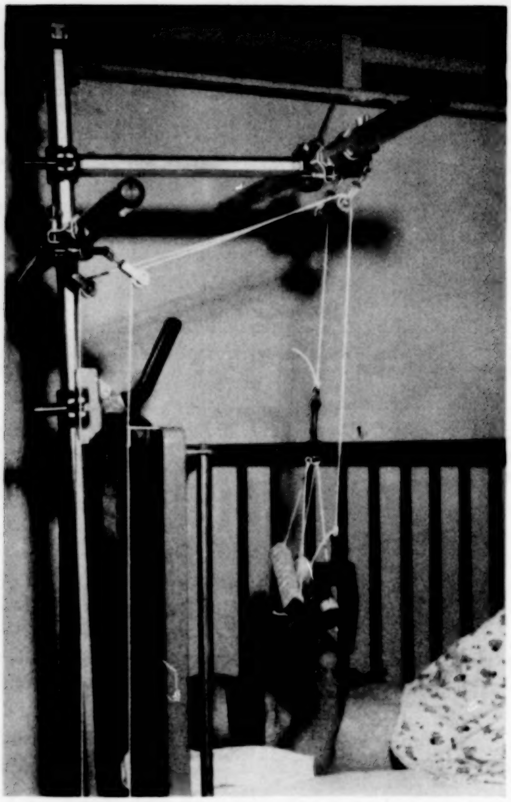

FIG. 2. Olecranon traction in use

5) A certain degree of mobility remains while treatment is in progress.

Critics of this method have emphasized the possibility of pin-tract infection, possible damage to the ulnar nerve, increased hospitalization of patient, lack of rigid immobilization of fracture site, and discomfort to the patient. In our series of forty cases submitted to skeletal traction, we experienced no instances of pin-tract infection and there has been no discomfort. There has not been any instance of damage to the ulnar nerve.

We regard the following as indications for olecranon traction:

1) Gross displacement
2) Vascular impairment
3) Instability

A brief review of technique is submitted: The area is prepared for surgery. Asepsis is mandatory. The elbow is held at ninety degrees with the hand in mid position. As the illustration shows (Fig. 3), with the elbow at right angles, the ulnar nerve falls away and the olecranon comes into prominence. The wire is

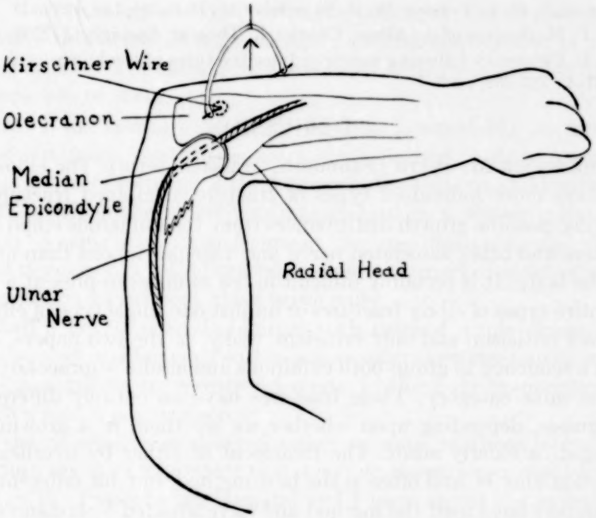

FIG. 3. Olecranon traction. Note relationship of the inserted pin to structures about the elbow joint.

inserted on the medial aspect. The tip is allowed to slide over the crest of the ulna at a point in line with the axis of the humerus. The tip is then scraped downward on the surface of the ulna until sufficient bone is engaged. The wire is then inserted, care being taken to assure that it is perpendicular to the long axis of the bone. The hand and forearm is supported over the face by use of a sling. The position of the forearm can be used to control rotation.

SUMMARY

1. One hundred and forty-five cases of supracondylar humeral fractures have been reviewed. Fifty-eight cases were examined in long term followup.
2. Forty-one per cent of the patients were considered "problem cases" requiring greater efforts to obtain satisfactory reduction.
3. Skeletal traction through the olecranon was used on forty patients with a close follow-up available on eighteen of them. This method of management has been satisfactory.
4. Traction, when used, should be instituted early.
5. Repeated manipulations are insulting to injured tissues and may lead to poor results.

REFERENCES

1. BLOUNT, W. P. *Fractures in Children.* Williams & Wilkins Co., Baltimore, 1955.
2. MADSEN, E. Supracondylar fractures of the humerus in children. J. Bone & Joint Surg., 37-B: 241–245, 1955.
3. MAYLAHN, D. J. AND FAHEY, J. J. Fractures of the elbow in children: Review of three hundred consecutive cases. J.A.M.A., 166: 220–228, 1958.

4. McLaughlin, H. L. *Trauma*. W. B. Saunders Co., Philadelphia, 1959.
5. Smith, F. M. *Surgery of the Elbow*. Charles C. Thomas, Springfield, 1954.
6. Smith, L. Deformity following supracondylar fractures of the humerus. J. Bone & Joint Surg. **42-A:** 235-252, 1960.

DISCUSSION

Dr. Frederick M. Smith (Falmouth, Massachusetts): The elbow as a single region offers more individual types of fracture, combined fractures, fracture-dislocations, possible growth disturbances from the numerous epiphysial ossification centers and other associated nerve and vascular lesions than any other one area in the body. It is certainly difficult in ten minutes to present a paper either on the entire types of elbow fractures or on just one single type of elbow fracture.

My chief criticism, and only criticism, really, of the two papers, is that there has been a tendency to group both children's and adults' supracondylar fractures under the same category. These fractures have an entirely different potential and prognosis, depending upon whether we see them in a growing child or a middle-aged or elderly adult. The treatment of either by overhead Kirschner wire traction may be and often is the best method, but for different reasons.

Both papers have used the method and have avoided Volkmann's ischemia in children, and this certainly should be commended. At the Presbyterian Hospital, before I left New York, we had up to 1955, 622 children's supracondylar fractures. We had used the overhead Kirschner wire traction in 85 of those cases, and we also had no cases of Volkmann's ischemia.

As shown by Dr. Franklin Wade, it is a great mistake to perform multiple manipulations. Surgeons, either orthopedic or general surgeons, or general practitioners, who treat many of these fractures, should have this point driven home to them, and they should be educated to call in someone who knows how to take the bull by the horns and get adequate definitive treatment instituted early, and by "early" I mean within the first two days, not within the first two weeks.

On the question of operation for supracondylar fractures in children it is rarely necessary, but occasionally it may be. In the 622 cases at the Presbyterian Hospital, if you omit the open or originally compound fractures, we operated upon only four patients. That is a very small percentage. If they are operated upon I believe that one should use Kirschner wire transfixion of the fracture site.

In the adult, if there are large fragments with little comminution, I think many of these are best treated by open reduction and internal fixation with screws, and I believe that to facilitate the reduction and the fixation the trans-olecranon approach is very often advisable. Dr. Cassebaum was one of the ones who popularized that. I have used it myself on numerous occasions and found it a very easy way to handle some of these fractures.

If one is going to make a trans-olecranon approach, I would suggest that before he divides the ulna he should make a drill hole down the ulna for the site of the lag screw to be used afterwards. Then the fragment will fall back into an anatomical position.

Dr. Conn, I was wondering if you had any primary ulnar nerve palsies in your fractures of the medial epicondyle where the fragment was displaced into the joint. We had 7 in 21 cases in a paper that I published a number of years ago. Five of these had been in cases that came to us with their original dislocation reduced before we got them.

In fracture of the lateral condyle in children, I would like to mention the possibility of non-union, and this is not entirely limited to those fractures that have had marked displacement of the fragment. We had one child with minimal displacement in which the elbow was immobilized in a plaster splint, but apparently that became loose; the fragment became displaced, and that child went on and developed a full-blown non-union with marked cubitus valgus deformity, and later a subsequent ulnar nerve palsy.

We also had a lateral condyle fracture with marked displacement that was replaced operatively and fastened with a catgut suture and went on to non-union. I don't think a catgut suture is really adequate. I believe the fragments should be fastened with a nail, a pin, or a screw.

There is the possibility of delayed union in some of these lateral condyle fractures. I just began to appreciate that a couple of years ago, and I found that we had two at the Presbyterian Hospital and I have one at the moment that I am treating currently. I feel it is certainly going to go on to union, but it is showing a definite delay.

Dr. Conn, I think that the Kirschner wire traction is really more important in the overall avoidance of vascular difficulties, et cetera, than it is in treating possible reverse carrying angles of the elbow. If you obtain a reverse carrying angle of the elbow it may look ugly, but it can be corrected later. If you get a Volkmann's paralysis, ischemia and contracture, there is little you can ever do for it.

Dr. Conn also mentioned one case of myositis ossificans in an undisplaced fracture of the radial head. I was wondering if possibly that case might have had an unrecognized dislocation of the elbow that either had been spontaneously reduced or had been pulled upon by a friend. That would account for the marked soft part pathology in the front of the elbow that predisposes to the development of myositis ossificans.

I would like to show three slides, if I may.

[Slide] This is a 5-year-old child who was knocked down by a car crossing a highway in New York. You can see that she had a rather severe, badly comminuted fracture of the lower humerus, a supracondylar fracture. Notice this particular fragment right here.

[Slide] This child was put up in Kirschner wire overhead traction. There was no other way you could hold it stable. You couldn't have reduced it by any closed means, and wire through the olecranon stabilized it. Here is this fragment. That was purposely ignored temporarily. This was four days after the original injury.

[Slide] This shows the same child four weeks after the injury. The fracture had healed; the plaster was taken off. There was an ulcer overlying that fragment; the child was admitted, the fragment was taken out, and here is the elbow one week later, in both lateral and antero-posterior views.

That child at the end of a year and a half had an absolutely perfect result.

You couldn't tell the difference between that elbow and the other except for a small pinhole scar.

Dr. Franklin Wade mentioned the author who remarked about the "unwise, unnecessary and uncomfortable" aspect of this type of traction. I agree with Dr. Wade. This is not right, and I don't think that you could have treated such a fracture as I have just shown by any other means. I think that was a wise method; I think it was a necessary method, and it certainly was a most comfortable method. I have never seen a child yet who has complained of pain from any of these pins used for traction in the olecranon and that is in nearly ninety cases.

DR. EDGAR L. GILCREEST (San Francisco, California): I wish to show you some slides of one case which I think gives us much information about how valuable traction is in the treatment of fractures in the proximity of joints.

[Slide] This particular fracture occurred in a man 58 years old, who weighed 220 pounds and was thrown 15 feet from a revolving wheel, sustaining 7 fractures, 3 of them compound, and 2 dislocations. The fracture that interests us most is the one in the first slide, which shows a compound supracondylar and intercondylar T fracture involving the elbow joint. I believe today most surgeons would do an open operation on a patient with such a fracture and thereby cause more trauma.

[Slide] You see in this slide that the shaft of the humerus has been driven down between the two separated condyles. By means of a pneumatic air tube the dislocated shoulder was gradually reduced, as was also the fracture of the shaft by means of traction alone, with the result that the patient obtained an almost complete recovery and was back at work in less than a year from the date of injury.

It requires patience in the treatment of these fractures, but one is often rewarded by the end results because the reduction of the fracture is accomplished without the trauma that would be occasioned by an operation with the introduction of foreign bodies.

DR. PRESTON A. WADE (New York, New York) (Closing): Although 414 cases of injuries to the elbow make a sizeable series to report, when these cases are separated into the various anatomical and clinical categories we found in many instances too small a number to be valuable in computing results on a percentage basis. However, we felt that in examining our end results we might improve on treatment in the future. We were looking particularly for errors and omissions in therapy and we feel that our study has been worth while in pointing out certain methods in treatment that might be helpful.

These cases were treated by many different surgeons, residents, some attending surgeons, both orthopedic and general surgeons. Almost every recognized form of treatment has been employed in each type of injury.

The displaced supracondylar fracture in children is one condition in which we feel that the results could be improved by the use of skeletal traction in certain cases rather than by reduction and immobilization in plaster. In six cases, in which a reverse carrying angle following treatment in plaster, we considered the failure to recognize inadequate reduction in the x-ray as the cause of the resulting deformity. We have always considered circulatory embarrassment to be an indication for skeletal traction, as Dr. Smith has indicated, but we feel that in those cases of displaced supracondylar fracture where x-rays can not assure us of a perfect reduction that skeletal traction is indicated.

We had no complications of skeletal traction in children and results in all of the cases treated in this manner were excellent, with good function and no deformity.

We did have, however, four complications of skeletal traction in the adults. Two of these cases were intractable elderly patients in which the wire had to be removed early, resulting in loss of position of fragments. Two others, however, became infected. The infection was not serious and did not involve the joint but necessitated removal of the wires early, so that the resulting limitation of motion was due not only to the stiffening resulting from infection, but also to loss of position of the fracture.

It is our rule to apply all skeletal traction in the operating room with the strictest aseptic precautions. These two infected cases had the wire inserted in the operating room. However, the wires were unthreaded and this may have been a factor in the resulting infection. We now use only threaded Kirschner wires to obviate the possibility of slipping of the wire.

We were interested to examine the results of our radial head fractures in which the head was removed, in order to ascertain whether or not the time interval between injury and operation had any effect on the end result. In our series it did not. All of the cases operated upon late, up to two or three weeks, had excellent results with no incidence of myositis ossificans.

One of the two cases of myositis ossificans was in an undisplaced fracture of the radial head. Dr. Smith has inquired whether or not this might have been a dislocation which had been reduced when it came to us. We have no evidence that it was.

The second case of myositis ossificans was in a case of syringomyelia in which there was a dislocation.

[Slide] Here is the dislocation

[Slide] and the reduction.

[Slide] Then, some months later, this advanced myositis ossificans. He does have motion, however, and no pain and, fortunately for us, does not want anything done about it.

Dr. Smith has asked if we had any ulnar nerve palsies in the medial epicondyle fracture. None was reported.

Dr. George J. Curry (Flint, Michigan) (Closing): I have been associated long enough with the management of supracondylar humeral fractures to have gone through a period during which there were a number of open reductions for the type of cases which have been discussed. Procedures of this type have been eliminated for the most part with the use of olecranon overhead traction.

I made a study of supracondylar humeral fracture management by olecranon traction for a ten-year period prior to the ten years that Dr. F. Wade reported, with the same conclusions. We have used olecranon traction occasionally in adults. May I also add that in the management of this type of fracture there should be a combination, at times, of open reduction along with the olecranon traction. The forty per cent that has been mentioned by Dr. Wade may be a little high, but it is as we observed it.

THE MANAGEMENT OF FRACTURES OF THE MANDIBULAR CONDYLE

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The comparative ease of fracture of the mandibular condyle and its relative inaccessibility offer many problems for treatment. The fracturing force, depending upon its severity, is usually indirect and transmitted from the symphysis along the horizontal ramus and upwards to the neck of the condyle. This force may be only sufficient to tear the joint capsule or of such magnitude as to shear off the neck and disrupt the joint contents. A fracture through the neck of the condyle may be associated with great displacement of the proximal fragment because of the disturbance of muscular balance. When the glenoid fossa is emptied of its contents from the severe pull of the lateral pterygoid muscle attached to the condyle and meniscus, the distance from the gonion to the skull is decreased, causing the occlusion of the teeth to be closed on the fractured side. This is a cardinal clinical sign of fracture dislocation of the condyle. Similarly, if the fracture dislocation is bilateral, the vertical distance is shortened on both sides and both molar areas prematurely occlude with a resultant open anterior bite. If the force of the blow is directed posteriorly, the condyle may rupture the wall of the auditory canal causing hemorrhage into the ear canal. This sign may mislead to the diagnosis of a basilar or temporal bone fracture.

This fracture may be often overlooked because of its frequent association with other fractures of the facial bones. The generalized edema and pain of the face can mask the condylar fracture resulting in failure to order the necessary x-rays. The ordinary anterior-posterior x-ray will not reveal all fractures of the condyle as it is partially obscured by the superimposition of the mastoid process, the petrous portion of the temporal bone, and the zygomatic process (Fig. 1). Special temporomandibular joint x-rays may be taken specifically to demonstrate this fracture.

The management of fractures of the mandibular condyle has been the subject of considerable controversy. It is stated by some that all such fractures and fracture dislocations may be handled simply by fixation of the mandible to the maxilla if teeth are present. These authors believe the risks of operation in this region outweigh the improvement in reduction (1, 3). They state that all unreduced fractures will heal by fibrosis or pseudo-arthrosis with satisfactory jaw function. There are only a few surgeons who advise an open reduction for fracture dislocations (2).

Read before the Twentieth Annual Session of The American Association for the Surgery of Trauma, Coronado, California, October 5–7, 1960.

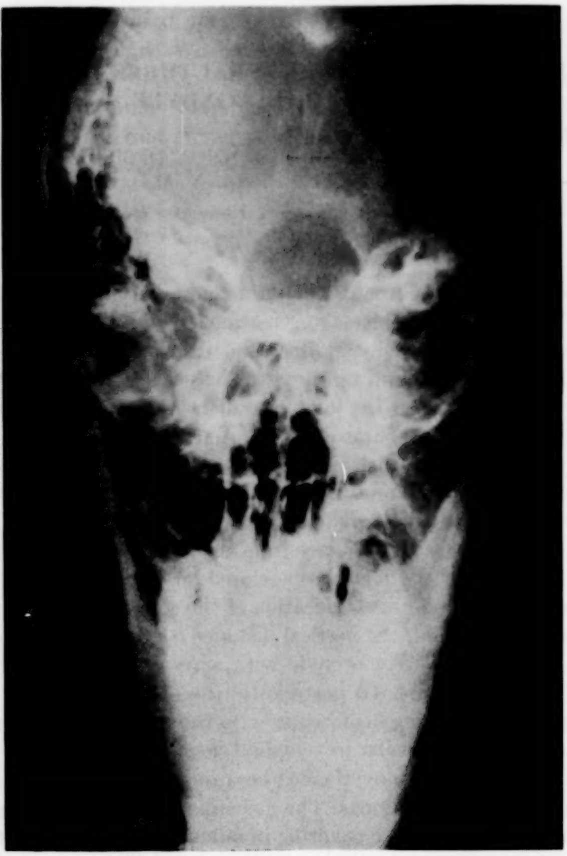

FIG. 1. Special x-ray demonstrating the condyle of the mandible

The arguments against open reduction for most fractures across the neck of the condyle are: 1) in most patients, with minimal or moderate displacement, healing by bony union, fibrosis or pseudo-arthrosis takes place with little or no resultant difficulty; 2) operation in this area involves a fair degree of risk of damage to the facial nerve; 3) the technique of adequately exposing the fracture site and temporomandibular joint is difficult.

We have recently studied the patients seen at the University Hospitals of Cleveland, St. Luke's Hospital, and the patients seen in the private practice of one of us (C. L. K.) over the ten year period from 1949 to 1959, with fractures through the neck of the mandibular condyle. Our purpose was to assess the results in those patients who have had open, operative reduction as compared to those managed by closed methods.

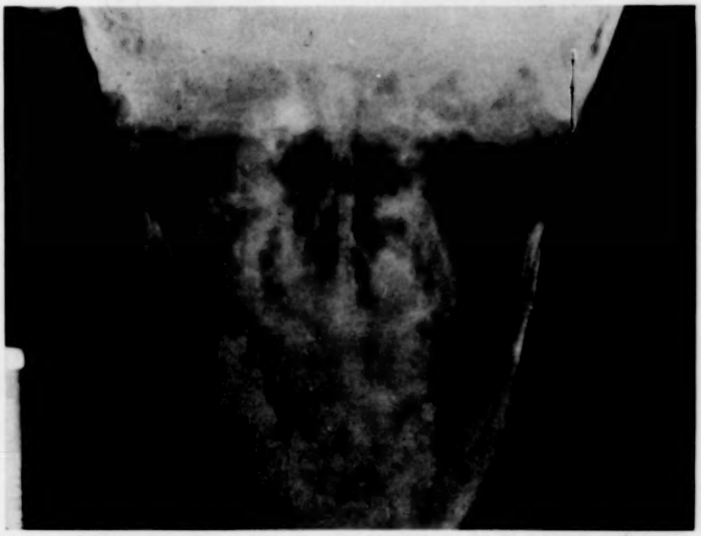

Fig. 2. Bilateral malunited fractured condyles causing pain for twenty years

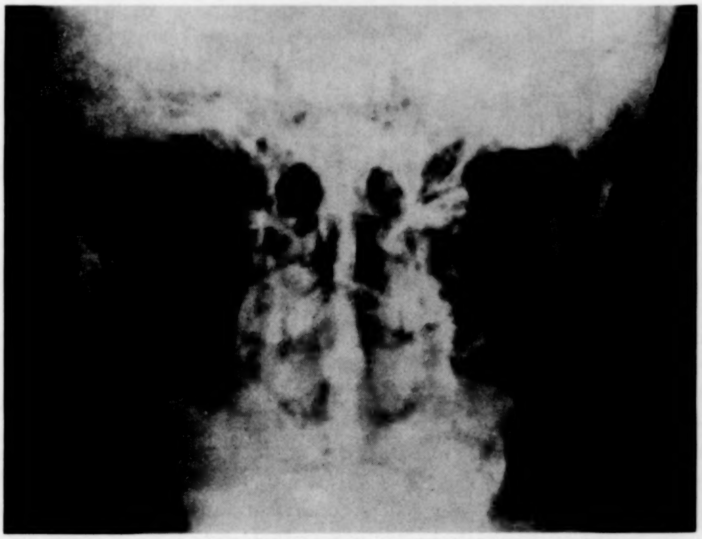

Fig. 3. Unreduced malunited fractured condyle causing severe pain necessitating resecting condyle.

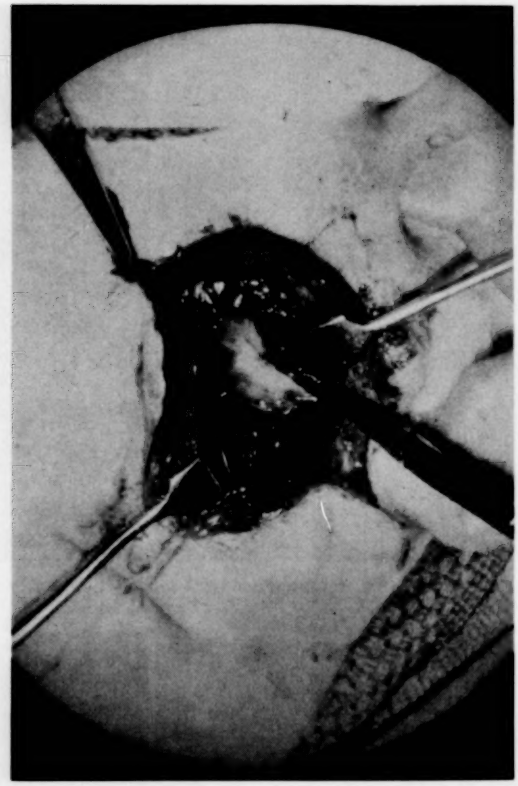

FIG. 4. Preauricular approach for open reduction of fractured condyle. An incision over the angle of the jaw may be necessary if the fracture is through the sigmoid notch.

STUDY GROUP

The case records, x-rays, and follow-up reports of a total of 30 patients were studied. This group was a small portion of the total number of patients seen during this period with other, more common, sites of fracture of the mandible. In this group, 22 patients were males, 8 were females, a ratio of more than 2 to 1. This reflects the greater proclivity of the male to jaw trauma. The group was divided into three age groups, 1) less than 20 years, 2) ages 20 to 40, and 3) ages 40 and above. There were 7 patients in the first group, 13 in the second, and 10 in the third.

In these 30 patients, 11 had a single fracture through one mandibular condyle: Nineteen patients had multiple fractures, either through both condylar necks or through one neck and another area of the body or ramus of the mandible. The procedures chosen in the management of these injuries were as follows. Labial arch bar wiring of the mandible to the maxilla, when teeth were present,

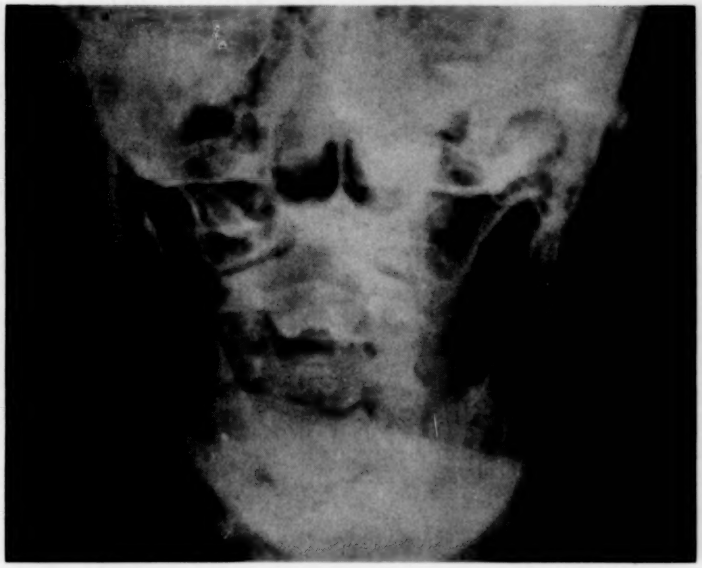

FIG. 5. Anterior-posterior x-ray showing lateral shift of the jaw due to shortening of the glenoidal gonion distance but not visualizing the condyle fracture.

FIG. 6. Lateral view of jaw showing the fractured condyle

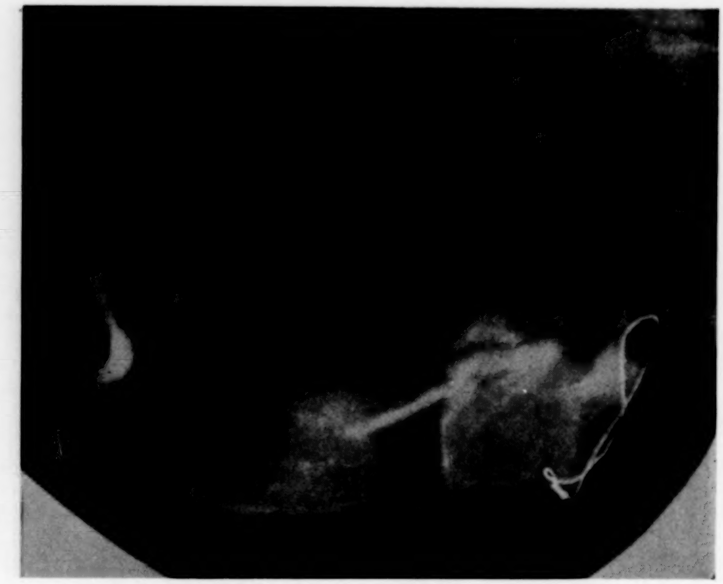

FIG. 7. Condyle replaced and held in position with a condylar gonion wire that is easily removed when healing is complete.

with fixation for six to eight weeks was used in 10 patients. Thirteen patients had operative reduction of the condylar fracture with wire fixation across the fracture site. Seven of these thirteen also had application of labial arch bar and wires for further fixation of other fractured areas. Seven patients in the series were managed without operative reduction or wire fixation of the mandible to the maxilla; the only therapy used was a temporary Barton head bandage dressing for a period of days.

RESULTS

The 7 patients treated with no fixation of the condylar fracture were young patients and had fractures with minimal displacement. Six of these patients did well and had no complaints referable to their mandible. One patient in this group was a seventy year old male who had had bilateral condylar fractures with displacement treated previously at another hospital with no fixation. He was seen twenty years later for chronic pain in both temporomandibular joints. No surgery was done and he was lost to follow up (Fig. 2).

Ten patients were treated with labial arch bar wires and rubber band traction, or with interdental wiring of the mandible to the maxilla. On follow up, only one of these patients had complaints referable to the mandible. She complained of pain in the displaced condyle and it was resected (Fig. 3). Jaw motion was adequate and painless in the remaining patients.

The 13 patients whose condylar fractures were reduced at operation and wired

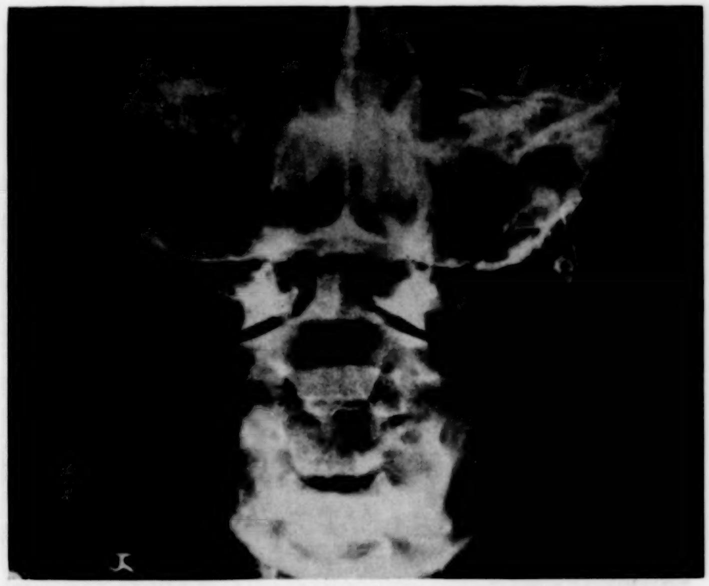

FIG. 8. Anterior-posterior view showing the condyle in good position

in place by stainless steel wire across the fracture site did well. These patients, in general, had the most severe fractures that were seen. There were more multiple fractures, more badly displaced fragments and greater areas of edentulism in this group than in the others. One patient had postoperative paresthesias over the temporal region for several weeks after surgery. There were no instances of seventh nerve damage in this group. Postoperatively, the dental occlusion was more normal in this group than in those treated by other methods. There was also a more normal excursion of motion in all planes.

DISCUSSION

From experience with the management of these fractures, conclusions are drawn that certain fractures through the condyle of the mandible should be reduced by the open method. These are the fractures that are severely displaced, with other comminuted fragments that are present, with the mandible representing a bag of bones, and with the loss or absence of teeth. This is particularly true in the completely edentulous mouth. In order to re-establish the normal distance between the glenoid fossa and the gonion of the mandible and in order to have a normal relationship between mandible and maxilla, all fragments should be replaced into their normal position if possible. This will result in a better occlusion of the teeth, a better excursion of the mandible, and freedom from pain.

TECHNIQUE OF OPERATION

The curved preauricular incision is made down through the superficial fascia (Fig. 4). With blunt and sharp dissection, the glenoid fossa is found under the

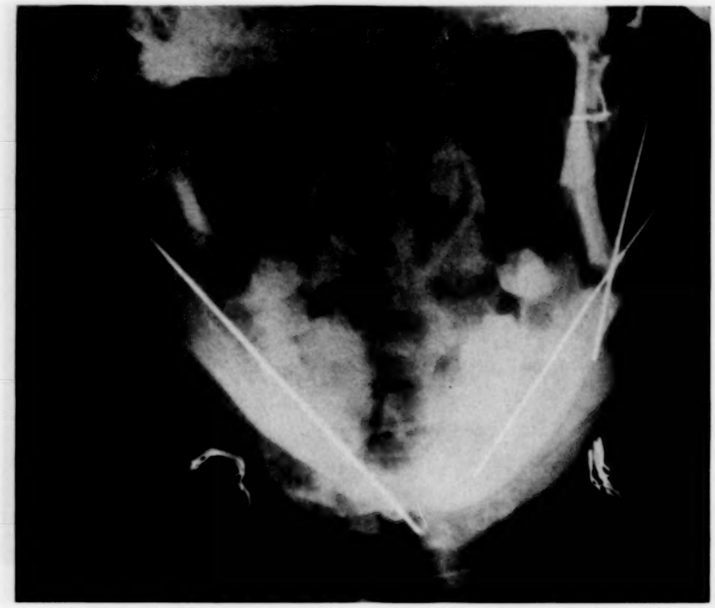

FIG. 9. Bilateral comminuted compound fractures of the mandible and its condyles with edentulism. Open reduction on both condyles and other fragments reduced with intramedullary pins.

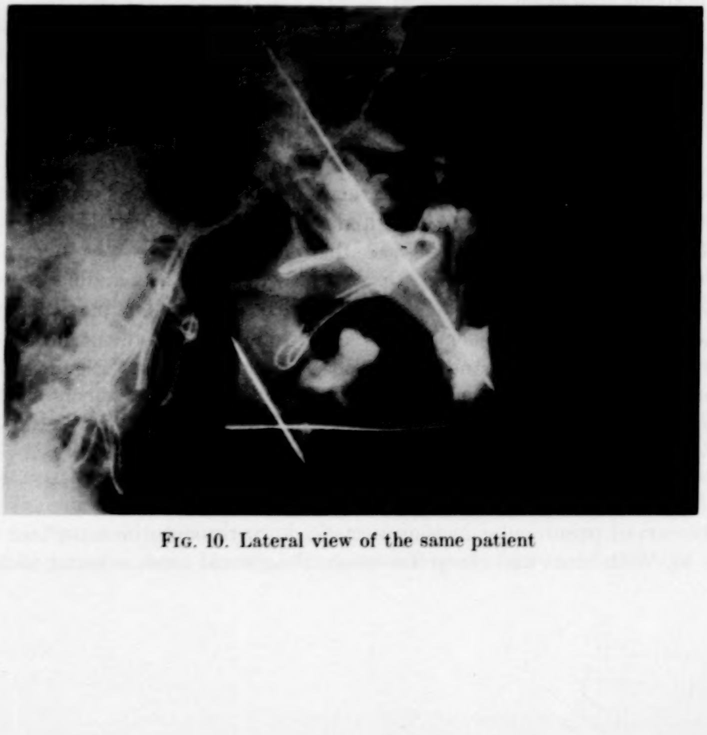

FIG. 10. Lateral view of the same patient

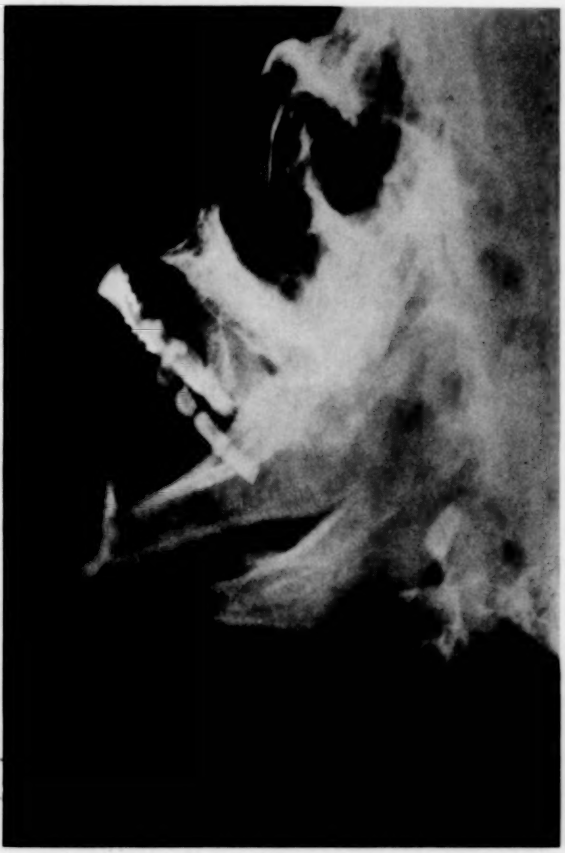

Fig. 11. Preoperative view of an edentulous mandible fractured through the symphysis and the condyle demonstrating the result of an indirect force.

zygoma. As stated previously, a goodly number of these fossae will be empty of their contents. The condyle may be very difficult to find lying high and anterior because of the pull of the lateral pterygoid muscle. The meniscus will be found to be torn as well as the capsule. It is very difficult to counteract the pull of the lateral pterygoid muscle on this bony fragment and frequently the condyle must be removed in its entirety and replaced as a free graft on top of the condylar neck. This is held in place by means of a #25 wire placed through drill holes (Figs. 5, 6, 7, 8). A meniscectomy must be done in order to establish the normal excursion of the condyle. We have not found any aseptic necrosis of the head of the condyle following this procedure. The remainder of the mandibular fragments are then reduced by threading them on a Kirschner wire or by drilling holes in each fragment and suturing with #25 stainless steel wire (Figs. 9, 10). In any event, an attempt must be made to replace each fragment in its original

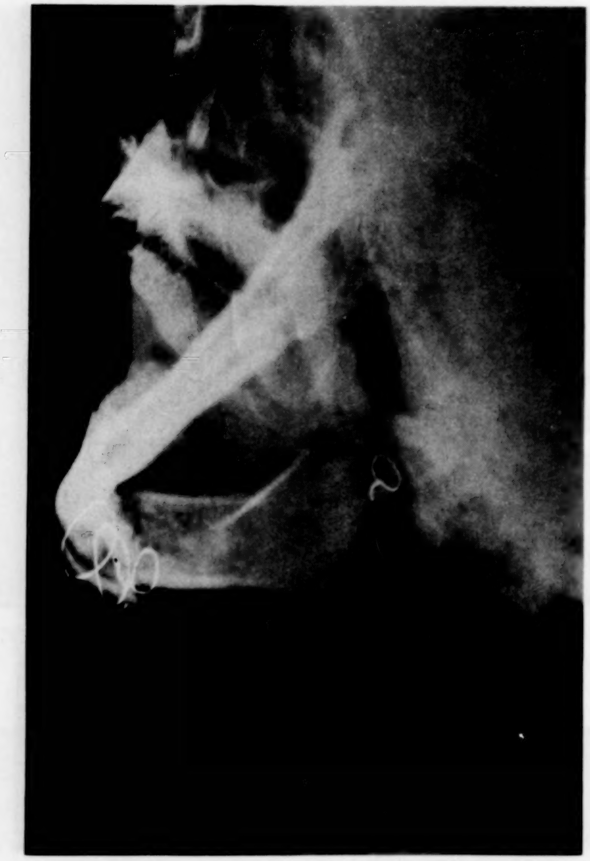

FIG. 12. Postoperative view of patient shown in fig. 11

position so that the normal measurements can be re-established. Interdental ligation is then applied until healing is complete (Figs. 11, 12).

CONCLUSION

The choice of management of the reduction of the fracture depends upon its severity, its association with other fractures, the age of the patient, and the presence or absence of teeth. It is felt that when severely comminuted fractures of the mandible, with or without edentulism, accompany severely displaced fracture of the condyle, open reduction should be performed. In addition bilateral condylar fractures, particularly in the edentulous patient, should have operative reduction. The results of careful surgery in this area are good and warrant its continued use in the management of these fractures.

REFERENCES

1. Fry, W. K., et al. *The Dental Treatment of Maxillo-Facial Injuries.* Blackwell, Oxford, 1942.
2. Hendrix, J. H., Jr., Sanders, S. G. and Green, B. Open reduction of mandibular condyle; A clinical and experimental study. Plast. & Reconstruct. Surg., **23:** 283–287, 1959.
3. Kazanjian, V. H. and Converse, J. M. *The Surgical Treatment of Facial Injuries.* William & Wilkins, Baltimore, 1949.

DISCUSSION

Dr. C. Steven Hatch (Idaho Falls, Idaho): I am pleased to commend Dr. Hermann and Dr. Kiehn for their presentation concerning fractures of the mandibular condyle, and I will limit my remarks to this paper.

At the beginning I should like to point out that my serving as a discusser stems neither from any unusually large experience with these fractures nor any unusual success with their care, but more from the difficulties that I have encountered in caring for a few of these patients, and also from an unwillingness to accept a current premise that immobilization for condylar fracture dislocation is likely to give as satisfactory a result as can be achieved by open surgery.

It occurs to me that there are few, if any, other areas where we accept as satisfactory a displaced or angulated fracture with a persistent dislocation. We have come to accept it here because of the difficulties and the poor results from surgery. These poor results have largely been the consequence of fear of facial nerve injury and resultant poor exposure and perhaps the frequent tendency to angulation and redislocation of these fractures. If these problems can be overcome, the more routine use of adequate reduction and fixation by open means would surely seem indicated.

Dr. Hermann and Dr. Kiehn have shown 13 cases in which, in a pre-auricular approach, they have had no facial nerve injury and apparently adequate exposure. This surely attests, I am sure those of you who have tried it will agree, to their care and skill in this surgical approach.

I should like to call attention to a safer and cosmetically more desirable incision described by Dr. Davidson, from England. He is an E. N. T. surgeon who has recommended an end-aural incision modified from that used in mastoidectomy. The joint is exposed by separating the cartilages in the external auditory canal. This approach affords adequate exposure with complete safety from facial nerve injury.

There are three additional suggestions in the paper which I believe are worthy of emphasis to protect against the angulation and redislocation. First, the separation of the pterygoid muscle attachments from the proximal fragment; second, removal of the fibro-cartilage, if necessary; and third, and this is not presented particularly with this point in mind, but I think it would apply: the threading of the small fragment with a Kirschner wire, attaching it to the body if necessary.

I believe more widespread experience with such techniques as these should prove helpful in raising our standard of care in these difficult problems.

A STUDY OF THE EFFECT OF OPEN AND CLOSED TREATMENT ON RATE OF HEALING AND COMPLICATIONS IN FRACTURES OF THE TIBIAL SHAFT

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Satisfactory results are obtained in a large proportion of fractures of the tibial shaft by closed reduction and application of a cast. However, in a substantial number of such fractures either satisfactory reduction cannot be obtained by the closed method, or having been obtained, cannot be maintained; in such cases open reduction and internal fixation becomes necessary. Because of the widespread opinion that open reduction inevitably leads to a prolongation of healing time and also has a greater likelihood of producing complications, there is often a tendency tc be excessively cautious in the application of this technique.

In order to define the relative results of open and closed treatment of tibial shaft fractures in our hands, a series of consecutive cases has been analyzed with respect to rate of healing and incidence of complications. Obviously random selection of the various methods of management could not reasonably be applied to such a study. Fractures treated by open reduction and internal fixation in general represented more severe injuries in terms of degree of comminution or were otherwise unable to be treated satisfactorily by closed reduction. In spite of the fact that this factor tends to produce some weighting of the results in favor of closed treatment, it was felt that such an analysis would be useful in defining the relative advantages and disadvantages of open as compared to closed management.

MATERIAL

One hundred consecutive fractures of the tibial shaft were studied. Patients under 21 years of age were arbitrarily excluded from the study. The great majority of patients were treated by the resident staff, whether by open or closed methods.

RESULTS (Table I)

Closed Treatment. Twenty-nine patients with simple fractures of the tibial shaft were initially treated by closed reduction and application of a cast. In four of these patients reduction was not maintained and subsequent open reduction and internal fixation was necessary. The remaining 25 patients obtained satisfactory healing without complications.

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* Markle Scholar in Medical Science.

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TABLE I

Overall results

	Total Cases	Good Result	Lost Reduction	Osteomyelitis	Delayed Union	Nonunion
Closed reduction						
Simple fracture	29	25	4	—	—	—
Comminuted fracture	29	20	7	—	1	1
Closed-pins						
Simple fracture	4	3	—	—	1	—
Comminuted fracture	3	1	—	—	—	2
Open reduction						
Screws	26	25	—	—	1*	—
Plate	6	2	—	2	2	—
Graft	3	3	—	—	—	—
Total	100	79	11	2	5	3

*** One patient with delayed union healed in eleven months. All other cases of delayed union and nonunion were treated by secondary bone graft with eventual union.**

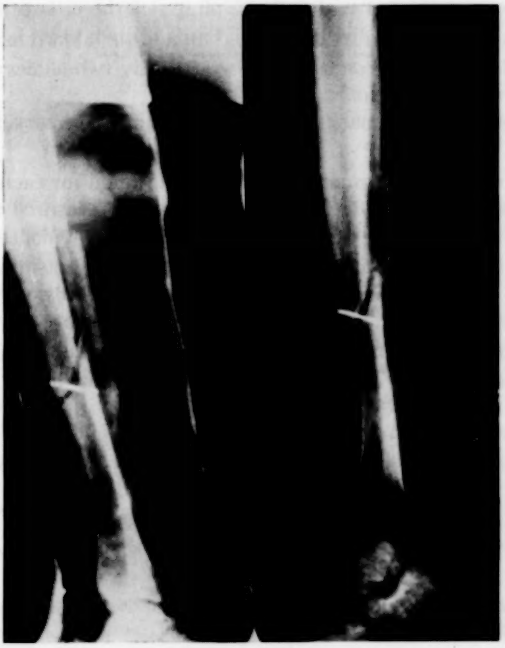

FIG. 1. Oblique fracture of tibia treated by open reduction and single transfixion screw. A. Immediate post-reduction film showing fragments held in separated position and head of screw broken off by improper attempt to secure tighter apposition by excessive force. B. Eight months later, with bone resorption, the separation is even wider. Union eventually was obtained at eleven months.

Twenty-nine patients with comminuted fractures were treated initially by closed reduction. Seven of these required subsequent open reduction because of unsatisfactory position or loss of reduction. One patient had delayed union and one had nonunion, each being treated by subsequent secondary bone graft. Twenty patients obtained a good result from the primary treatment.

Seven patients, four with simple fractures and three with comminuted fractures, were treated by closed reduction with transfixion pins above and below the fracture site incorporated in the plaster cast. Of these seven patients, one had delayed union and two had nonunion, each requiring secondary open reduction and bone graft.

Open Reduction. In this group of cases simple and comminuted fractures were considered together since the success of treatment and incidence of complications appeared not to be affected by this factor.

Twenty-six patients had open reduction and internal fixation by transfixion screws. All of these cases achieved primary healing except one in whom delayed union occurred, with healing being obtained in eleven months. In this single case incorrect use of a transfixion screw resulted in the fracture ends being held in a separated position (Fig. 1).

Six patients were treated with a bone plate. Of these, two developed osteomyelitis which responded to treatment and an additional two had delayed union which responded well to secondary bone graft. Only two achieved a good result from the primary treatment.

Three patients with primary bone grafts obtained primary healing without complications.

The mean time interval from injury to clinical union for each of the different groups is illustrated in Table II. Healing time was measured from the occurrence of the fracture to the stage at which radiologic evidence of healing and clinical examination warranted removal of the cast. For simple fractures the mean interval of healing with closed treatment was 14.9 weeks and with open treatment 16.3 weeks, a difference which is not significant.

For comminuted fractures the mean interval to healing was 18.9 weeks with closed treatment and 17.7 weeks with open treatment, again an insignificant

TABLE II

Average Healing Time

Fracture	Treatment	Healing Time, Weeks ± S.D.
A. Simple	Closed	14.9 ± 4.6
B. Simple	Open	16.3 ± 5.0
C. Comminuted	Closed	18.9 ± 6.8
D. Comminuted	Open	17.7 ± 5.9

Mean intervals from time of fracture to clinical union. Cases with nonunion are excluded from calculations. By statistical analysis group C, comminuted fractures—closed reduction, is found to have a significantly longer healing time than group A, simple fractures—closed reduction. There is no significant difference between any other groups.

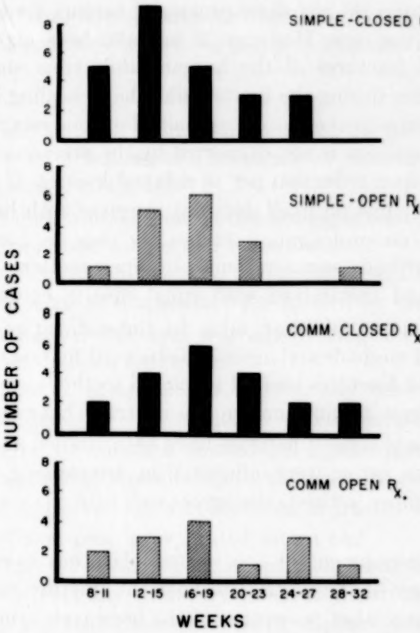

FIG. 2. Dispersion of healing times in the various groups. Cases of nonunion are not included.

difference. Curiously, the healing time was significantly prolonged in comminuted fractures treated by closed methods as compared to simple fractures; however, no significant prolongation of healing time was apparent in comminuted fractures treated by the open method.

In Fig. 2 the dispersion of healing time in various groups is plotted individually.

DISCUSSION

Because of theoretical or actual hazards open reduction and internal fixation of fractures of the tibial shaft are frequently employed only when closed reduction fails. The actual probability of such additional hazards being produced by open reduction is difficult to assess.

One must make the assumption that a certain possibility of infection attends any surgical procedure and at present there is no way of entirely eliminating such an eventuality. However, whether the very small incidence of such infection is sufficient justification for avoiding an optimal method of treatment is another matter. There is no doubt that the use of antibiotics has markedly improved the successful management of such infections.

A more commonly considered disadvantage of open reduction has been the supposed adverse effect on fracture healing. Other authors (2) have concluded that simple fractures heal more rapidly than comminuted ones and that compound (open) fractures do not show prolonged healing time; these findings are in agreement with our own. However, it has also been expressed by Urist (2) that "comminuted fractures of the human adult tibia should be considered nonoperable fractures during the first six months of healing because the trauma added by surgery exceeds the normal capacity for bone regeneration in this area of skeleton." This opinion is not supported by the present series since there was not evidence that open reduction per se delayed healing. If one can accept the concept that open reduction itself does not interfere with healing, then the observed findings of no prolongation of healing time in comminuted fractures treated by open methods seems rational; by open methods excellent reduction can be obtained and maintained with equal ease in comminuted and simple fractures. However, comminution adds to the difficulties of maintenance of reduction by closed methods and again the observed finding of prolonged healing time in comminuted fractures treated by closed methods seems reasonable. It is possible that previous assumptions to the contrary have been due to the fact that noncomparable groups of patients have been studied and that factors other than open reduction per se were influential in determining the rate of healing. The mean healing times in this series agrees well with the studies of Jackson and MacNab (1).

Although the development of the slotted plate has been an improvement, the natural tendency of the plate is to hold the fracture ends in a fixed longitudinal relationship so that resorption of the bone ends tends to produce a gap between the fragments which might delay healing. This effect also occurs with transfixion pins held in a fixed position in plaster. This concept would appear to offer an adequate explanation for the markedly increased incidence of delayed union and nonunion in fractures treated by these methods.

A similar effect should not obtain in fractures which are oblique or spiral and can be treated by single or multiple screw fixation. This concept is supported by the fact that the only patient with screw fixation who developed delayed union had improper reduction of the fracture and the fracture ends were held in a separated position by the screw.

These theoretical considerations have been substantiated by others (1, 3) as well as in this series, since uniformly good results have been obtained in patients subjected to multiple screw fixation of oblique or spiral fractures or patients treated by primary bone graft. In the latter event the benefits of the graft may offset the potential loss of healing by longitudinal fixation. The early removal of transfixion pins, which would tend to allow the fracture ends to move together as resorption develops, should lessen the complication rate with this type of management.

Although the overall complication rate was higher in patients treated by open reduction, a more detailed inspection of these patients reveals that almost fall of the poor results were attributable to a single type of internal fixation namely a bone plate. Similar difficulties with this method have been recorded by others. However, in assessing the relative merits of various methods of management, the competence of the surgeon in a particular technique may well be the most important factor and it may be that this factor has influenced the unsatisfactory results achieved with bone plates in this and other series.

SUMMARY

1. A consecutive series of one hundred fractures of the tibia has been studied with respect to the rate of healing and incidence of complications in fractures treated by open and closed methods.

2. Open reduction and internal fixation did not significantly prolong the time of healing over that obtained with closed reduction.

3. There was a prolonged healing time in comminuted fractures treated by closed method as compared to simple fractures treated by closed methods . The healing rate of comminuted fractures was not prolonged over that of simple fractures when treated by open reduction.

4. A higher incidence of complications, particularly delayed union and nonunion, was observed following open reduction. These complications, with only one exception, occurred in fractures treated by a bone plate, which tends to maintain a fixed longitudinal relationship of the fracture ends. A similar high incidence of delayed and nonunion was observed in fractures treated by closed reduction with transfixion pins incorporated into a cast.

5. It is suggested that when carried out in optimum fashion internal reduction may be performed without any necessary inherent disadvantage in respect to rate of bone healing, and that the incidence of complications should be low.

REFERENCES

1. Jackson, R. W. and MacNab, I. Fractures of the shaft of the tibia; a clinical and experimental study. Am. J. Surg., **97**: 543–557, 1959.
2. Urist, M. R., Mazet, R., Jr., and McLean, F. C. Pathogenesis and treatment of delayed union and non union. J. Bone & Joint Surg., **36**-A: 931–968, 1954.
3. White, A. W. M. An analysis of 111 cases of fractures of the tibia and fibula. Canad. M.A.J., **71**: 449–455, 1954.

DISCUSSION

Dr. Edwin F. Cave (Boston, Massachusetts): This subject of tibial fractures, of course, is one which we always discuss and listen to with interest, and as to whether or not fractures should be treated by closed methods or open methods, the discussion will continue.

My chief interest in this problem of fracture healing is how to avoid disasters, such as we see occurring more and more in our country, and I fear more and more in Europe, having seen at the recent meeting of the International Society of Orthopaedic Surgery and Traumatology some of the demonstrations of various types of apparatus which are being used, particularly the very large medullary nails which are being inserted and which I must say I view with some apprehension.

America has been accused of all of these faults, but I think they are spreading to other parts of the world. How can we avoid these troubles?

Well, a tibial fracture is so accessible; it is so tempting for the surgeon; it is so easy to get at that more and more are being subjected to operation. I agree heartily with the point of view expressed by Professor Trueta. "Keep the closed fracture closed," as John Moore said last year in his Presidental Address before the American Orthopaedic Association, and showed some frightful disasters from open treatment. They appear to be increasing. How can we avoid them?

(Slide) I recently reviewed 103 cases of bone grafting which I have done; I think almost all of these in the last eight or ten years; and here were the locations of the fractures. More important, however, is the next slide (slide), which shows in 67 cases of closed fractures the causes of failure of healing of bone. And you see at the head of the list is "improper operative interference." Failure of treatment can come from poor selection of case for operation, it can come from poor technique, it can come from poor postoperative care, and can happen most of all, I think, by failure of the surgeon to evaluate the x-ray film and to know when bone is healing or when it is healed. So, improper operative interference was the commonest cause of nonunion, followed by inadequate closed reduction, inadequate external fixation, and so on.

(Slide) Then, in 36 open fractures, second on the list of causes of nonunion was "improper operative interference." The general surgeon is not making all of these mistakes; the general practitioner is not making all of them. The orthopedic surgeon is contributing his share as is the fracture surgeon.

How can we prevent these errors? Only by better postgraduate training, better fundamental knowledge; and I think most of all in being able to evaluate the x-ray film and to know when bone is healing.

In this country we are seeing Parham bands used more often, particularly in skiing fractures. They are being taken off at the end of six or eight weeks, and many of these patients are being allowed to ambulate, with or without weight bearing, at the end of that time. I am seeing an increasing number of disasters from the use of Parham bands. Their utilization is not confined to New England; they are being employed in the western part of this country as well. So, the Parham band comes in for its share of criticism.

Recently at the Pan-Pacific Surgical Association meeting in Honolulu we discussed this subject and the Parham band was taken over the coals in a big way. However, it is a very useful piece of apparatus when it is properly used and the fracture properly evaluated afterwards.

But if the Parham band is used I think it should be left in place for a long period of time. I personally have not seen one bone fracture through a Parham band. That is a broad statement, and perhaps I am wrong, but I am sure more disasters come from removing the bands too soon.

These, then, are the problems. Fractures, as you have seen from these three papers, will heal, no matter what form of treatment is used, in an extremely high percentage of cases. The disasters are the things we are trying to avoid. The disasters are largely in the surgeon's hands.

DR. MURRAY N. ANDERSEN (Buffalo, New York): I was very much interested in the excellent analysis presented by Dr. Cave, and I note in his study of the causes of non-union that he shows approximately the same number of cases of non-union being produced by inadequate external fixation and inadequate reduction as by improper operative interference. So I think that it is clear that non-union can result from either technique, improperly used.

I would not like to leave the impression that I am championing open reduction as *opposed* to closed reduction. I don't think they are opposing techniques but complementary techniques. In our institution, as I think probably in most of yours, the initial elective treatment is closed, and operative interference is used when closed reduction fails or if the fracture is unsuitable for closed reduction.

THE TREATMENT OF TRAUMATIC INJURIES OF THE COLON

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Most of the experience in dealing with traumatic wounds of the colon has been dictated by the results obtained from two world conflicts, the Korean "police action", and the treatment of civilians with wounds of the colon (1, 3–11). This experience, while valuable, needs constant re-evaluation. In dealing with traumatic injuries of the colon, it is necessary to use considerable judgement and not attempt to treat all injuries to this structure in the same fashion. As a result of this study, we suggest individual appraisal of each colon injury, and the method applied which will be productive of the best result.

This report deals with colon injuries seen between January 1, 1955, and December 31, 1959, at the University and Veterans Administration Hospitals, Birmingham, Alabama. Most of these cases were treated by the resident staffs of these hospitals and are consecutive cases. During this period there were 403 penetrating wounds of the abdomen caused by stabs, bullets, or shot-gun blasts. All were explored. No cases of blunt trauma, nonpenetrating or instrumental trauma to the large bowel are included in this series. Of these 403 cases, 58 or 14.3% sustained wounds of the large bowel (Table I). We will review these cases from the standpoint of incidence, pre-operative and operative management, morbidity, mortality, and length of hospital stay. We should like to document the principle of primary repair and exteriorization followed by delayed return of the segment to the abdomen.

Incidence of Colon Injury

In this series as would be expected, males outnumbered females, there being 46 males and 12 females. The age of the patients ranged from 32 months (an innocent bystander) to 56 years, and the second and third decades led the field (Table II). There were 41 bullet wounds (rifle and pistol), 9 shot-gun blasts, and 8 stab wounds.

Factors Influencing Mortality

Unlike war injuries where considerable delay is caused by transport and triage, all of these patients were transported directly to the hospital by ambulance or pushcart, and were usually seen by a physician within a half an hour from the time of wounding. All of these patients were taken to surgery within 6 hours and most had definitive operations in three hours. The lack of associated grievous wounds and soft tissue trauma is reflected in our mortality figures since only one patient had trauma to structures outside of the peritoneal cavity.

Read before the Twentieth Annual Session of The American Association for the Surgery of Trauma, Coronado, California, October 5–7, 1960.

TABLE I

Penetrating Abdominal Wounds

Year	Total Wounds	COLON INJURY		
		Stab	Bullet	Shotgun
1955	62	0	7	3
1956	86	1	4	1
1957	82	2	5	3
1958	95	1	7	2
1959	78	4	18	0
Totals	403	8	41	9
58 Colon Injuries — 14.3 %				

TABLE II

Colon Injury as to Age and Sex

Males....... 48

Females..... 10

32 Months to 56 Years

Pre-Operative Care

All patients on arrival at the emergency room had a rapid physical examination and had blood drawn for cross matching and typing during the placement of a venous catheter usually in an upper extremity. A catheter was placed in the bladder to assess possible injury to the urinary tract and the efficacy of resuscitative measures. Rectal examination was routine and if gross blood was seen on the gloved finger, sigmoidoscopy was performed. X-ray examination was not routinely carried out except in shot-gun wounds and in bullet wounds where there was a single wound of entrance. Such a study enables a rapid estimate of the probable extent of injury and the involvement of thoracic viscera.

Any patient who did not respond by stabilization of vital signs within 90 minutes of the administration of 1500 cc's of whole blood was immediately taken to the operating room.

Operative Management

General anesthesia administered by the endotracheal route was the method of choice for all patients in this series. Regardless of the wound site, all patients were explored through a long midline incision or a long pararectus incision. This type of approach permitted rapid entry of the abdomen and adequate visualization of the structures. Hemorrhage was controlled prior to any exploration of the abdomen. Exploration was performed in systematic fashion starting in the area in which contamination was least likely. The liver, spleen, and diaphragm were first examined, then the stomach with division of the gastro-colic omentum to permit the posterior aspect to be visualized as well as the pancreas. If there was hematoma or bile staining of the periduodenal tissues, the duodenum was

TABLE III

Operative Treatment of Colon Wounds

1. **Simple Closure**
   - *A. Stab Wounds*
   - *B. Isolated Pellet Injuries From Shotgun Blasts*
2. **Resection of Wounded Area and Primary Anastomosis of**
   - *A. Wounds of Terminal Ileum and Cecum*
   - *B. Cecum*
   - *C. Ascending Colon*
3. **Primary Repair and Exteriorization of the Wounded Segment Where Trauma Was Due to Missiles (Bullets)**
4. **Immediate Proximal Colostomy In**
   - *A. Multiple Wounds of the Colon*
   - *B. Wounds of the Recto-Sigmoid and Rectum*
   - *C. Gross Fecal Contamination*
5. **Exteriorization of Bowel Adjacent to Wounds of Mesocolon**
6. **Pre-Sacral Drainage For All Wounds of Recto-Sigmoid and Rectum**

TABLE IV

Site of Colon Injury

Transverse	**20**
Hepatic Flexure	**1**
Mesocolon	**2**
Splenic Flexure	**3**
Ascending Colon	**0**
Descending Colon	**5**
Rectum	**3**
Sigmoid	**9**
Cecum	**5**
Multiple	**10**
	58

Cecum and Ascending Colon	*2*
Transverse Colon	*2*
Sigmoid Colon	*1*
Ascending and Transverse Colon	*1*
Cecum and Transverse Colon	*1*
Rectum and Sigmoid Colon	*2*
Cecum and Terminal Ileum	*1*
	10

mobilized and examined. If there were hematomata of the retroperitoneal tissues the kidneys were examined and injury to the ureters was ascertained. The small bowel was examined from the ligament of Treitz to the ileo-cecal valve. The colon was next examined in its entirety, mobilizing the retroperitoneal portions as well as the recto-sigmoid and rectum. The fact that there were only 13 patients without associated injury to other structures makes a thorough exploration mandatory. Irrigation of the peritoneal cavity with saline and the use of flank drains was routine. Closure of the exploratory wound was effected by retention sutures with interrupted silk sutures in the skin. When there is gross fecal contamination only retention sutures should be placed, and the skin closed secondarily (2).

Wounds of the colon were treated as follows:

1. Simple closure (two layers) in all cases of stab wounds and isolated pellet injuries from shot-gun blasts.

2. Resection of wounds in the cecum, ascending colon, or when the cecum and terminal ileum were involved.

TABLE V

Associated Trauma to Other Structures

Stomach	**5**
Small Bowel	**22**
Kidney	**2**
Liver	**5**
Gallbladder	**2**
Duodenum	**3**
Great Vessels	**3**
Bladder	**2**
Spleen	**1**
	45

TABLE VI

Complications—Non-Fatal

Wound Infection	**5**
Breakdown of Primary Suture In Exteriorized Loop	**7**
Intestinal Obstruction	**2**
Abscess	**2**
Sub-Diaphragmatic and Rectal	***1***
Mesenteric	***1***
Wound Dehiscence	**1**
Stress Ulcer	**1**
	18

3. Primary repair and exteriorization of the wounded segment when trauma was due to missiles (bullets).

4. Immediate colostomy in all cases after closure of multiple wounds in the colon, when the recto-sigmoid or rectum was wounded or when there was gross fecal contamination.

5. Exteriorization of the bowel in areas where the adjacent mesocolon was injured (12).

6. Presacral drainage for wounds of recto-sigmoid and rectum (Table III).

The majority of these wounds were in the transverse colon and there were 10 cases of multiple wounds of the colon (Table IV).

Trauma to Other Structures

There were only 13 cases in this series who did not have associated trauma to other structures. As would be expected, injury to the small bowel was most common and there were three associated great vessel injuries (Table V).

Complications—Non-Fatal

There were 33 patients who had a smooth course with the combination of procedures outlined. Of interest was one patient who developed a bleeding stress

TABLE VII

Complications—Fatal

Renal Shutdown and Infection	**4**
Irreversible Shock, Evisceration, Infection	**1**
	5

ulcer necessitating the performance of a hemi-gastrectomy and vagotomy. Two patients in this series were again shot while awaiting the closure of the colostomy fashioned for their primary wounding (Table VI).

Complications—Fatal

The most lethal weapon in this series of cases was the shot-gun. This weapon accounted for four of the five deaths reported. There was one death from multiple bullet wounds (rifle) and no deaths from stab wounds. All cases expiring did so from a combination of irreversible shock, infection, and renal shutdown. The mortality in this series was 8.6%. (Table VII)

DISCUSSION

Each case was individually assessed at the time of operation and decision for the method of treatment made at that time. No attempt at primary closure of any wound of the colon was attempted regardless of the type of trauma if more than two-thirds of the circumference of the antimesenteric portion of the colon was involved.

In 18 cases injury was such that we repaired and exteriorized the wounded segment. This consisted simply of a loop of colon with the repaired wound at the apex. It is most important in the exteriorization of this loop to avoid any tension which would cause retraction. This may best be done by mobilizing the hepatic or splenic flexures as need be. There were 12 cases in which the colon wound was healed at the fifth day. In 10 patients these loops were then returned to the abdomen. All recovered without incident. In 2 cases the suture line was intact but since intestinal obstruction developed it was necessary to open the exteriorized wounded loop to function as a temporary colostomy. Both of these patients went on to complete recovery. In six cases the primary repair failed to heal and the loop was further divided, with subsequent management as a temporary colostomy and recovery.

We agree with others that civilian injuries of the colon consisting chiefly of stab wounds and low velocity missile wounds do not require routine colostomy and exteriorization in the same way that military injuries do. On the other hand we feel that it is unwise to endorse primary suture and immediate return to the abdomen because of the difficulty in predicting the integrity of the anastomotic repair. We believe that the principle of exteriorization of the repaired segment with delayed return to the abdomen is far safer and effects the desired reduction in morbidity, mortality, and length of hospital stay.

TABLE VIII

Results of Operative Treatment

	No. of Cases	Deaths	Ave. Hosp. Stay (Days)
Repair with Exteriorization and Replacement 5th Day	11	0	17
Resection and Anastomosis	6	0	14
Primary Suture	10	0	17
Repair with Exteriorization and Breakdown	7	0	21
Repair with Primary Colostomy	21	4	29
Primary Suture with Pre-Sacral Drainage	1	0	20
Exteriorization without Repair	1	0	22
Resection Wounded Segment and Colostomy	1	1	Died 1st Hosp. Day
Resection with Exteriorization of Anastomosis	1	0	32
	†59	5	20.3

† *One Patient Had Two Separate Admissions For Colon Wounds*

Primary colostomy was performed in all cases having wounds of the recto-sigmoid or rectum.

Wounds of the mesocolon were repaired after control of hemorrhage after which that portion of the colon adjacent was exteriorized.

In accordance with the reports of others is the fact that the more injuries to adjacent organs which occur concommittantly with the colon wound the higher the mobidity and mortality. When five other organs in addition to the colon were injured there were no survivors (3). The average length of hospital stay for all cases regardless of treatment in this series was 20.3 hospital days. For resection and anastomosis the average hospital stay was 14 days. For repair with exteriorization and replacement of the wounded segment on the 5th day, the average stay was 17 days. Average stay for primary repair and replacement was 17 days and where primary colostomy was performed with or without repair average hospital stay including closure of colostomy was 29 days reflecting the more serious nature of the initial wounding. (Table VIII)

CONCLUSIONS

1. Fifty-eight wounds of the colon due to penetrating abdominal trauma have been presented and documented.

2. A mortality of 8.6% and an average hospital stay of 20.3 days was achieved by the following regime for colon wounds:

a. Simple closure (two layers) in all cases of stab wounds and isolated pellet injuries from shot-gun blasts.

b. Resection of wounds in the cecum, ascending colon or when the cecum and terminal ileum were involved.

c. Primary repair and exteriorization of the wounded segment when trauma was due to missiles (bullets).

d. Immediate colostomy in all cases after closure of multiple wounds in the colon, when the recto-sigmoid or rectum was wounded and when there was gross fecal contamination.

e. Exteriorization of the bowel in areas where the adjacent mesocolon was injured.

f. Pre-sacral drainage for wounds of the rectosigmoid and rectum.

3. Primary repair of the colon wound with exteriorization and delayed return to the abdomen introduces a factor of safety in the management of civilian injuries of the colon.

REFERENCES

1. Boland, F. K. Injuries of colon; review of 62 cases in Negro patients. Am. J. Surg., **46:** 126–130, 1939.
2. Christensen, N., Ignatius, J. and Mathewson, C. Jr. Treatment of injuries to the large bowel in civilian practice. Am. J. Surg., **89:** 753–758, 1955.
3. Chunn, C. S. Wounds of the colon and rectum. J. Florida M.A., **34:** 269–276, 1947–48 (Nov. 1947)
4. Flynn, J. E. Wounds of the colon and rectum. Am. J. Surg., **73:** 450–467, 1947.
5. Graham, A. S. Penetrating wounds of the colon. S. Clin. North America, **38:** 1639–1647, 1958.
6. Office of the Surgeon General, Circular Letter 178, 1943.
7. Ogilvie, W. H. Abdominal wounds in the Western Desert. Surg., Gynec. & Obst., **78:** 225–238, 1944.
8. Poer, D. H. Evaluation of colostomy for present day surgery: review of 4,939 cases of injury of colon and rectum. A.M.A. Arch. Surg., **61:** 1058–1065, 1950.
9. Pontius, R. G., Creech, O. Jr., and DeBakey, M. E. Management of large bowel injuries in civilian practice. Ann. Surg., **146:** 291–295, 1957.
10. Roof, W. R., Morris, G. C., Jr., and DeBakey, M. E. Management of perforating injuries to the colon in civilian practice. Am. J. Surg., **99:** 641–645, 1960.
11. Siler, V. E. and Bebb, K. C. Trauma to perineum, anus, rectum and colon. Am. J Surg., **80:** 652–662, 1950.
12. Trabue, C. C. Injuries to the colon and closure of colostomies. J. Tennessee M.A., **41:** 14–20, 1948.

DISCUSSION

Dr. Chester C. Guy (Chicago, Illinois): Years ago I participated in the preparation of a paper on "Peacetime Bullet Wounds of the Abdomen," published by Drs. Oberhelman and LeCount in "The Archives of Surgery" in 1936. This report included a rather exhaustive survey of the literature on these injuries, and it might interest this audience to know that apparently the first laparotomy for a bullet wound of the abdomen was performed by a Dr. Newell, of New Jersey, in 1847. It wasn't until 1882 that a Dr. Sims insisted that these cases should be explored, and in 1887 the American Surgical Association had a debate on the pros and cons of abdominal exploration for bullet wounds. The treatment of abdominal bullet wounds is one of the distinctly American contributions to the surgical literature, and our Southern colleagues in the past, as of today, have been the most conspicuous in this field.

William MacCormac, an Englishman, said in 1887, "In America everyone carries a revolver and often uses it on small provocation." In 1898, Brown said that he had no doubt that there had been probably a thousand gunshot wounds of the abdomen in the previous ten or twelve years in Birmingham, Alabama. Dr. Patton's report for five years suggests that shooting is still a popular way to settle arguments in his neighborhood.

The New Orleans Charity Hospital has been referred to as a laboratory for research on bullet wounds of the abdomen, and in the decade from 1900 to 1910 there were more such wounds of that type observed there than occurred in the Spanish-American War, according to Van Schaick in 1927. Being from Chicago, I can not resist the temptation to observe that my city may have a reputation for shootings, but other cities have the cases.

In 1936 we collected reports over the past forty years of bullet wounds of the abdomen, a total of 1494 cases with a mortality of 53 per cent. Between 1911 and 1924 at the Cook County Hospital there were 301 such patients operated upon, and of these there were 17 that had bullet wounds of the colon only. The colon and other viscera were injured in an additional 83 patients. The mortality rates in these two groups were 47 per cent and 83 per cent.

We previously emphasized that shotgun wounds deserve a separate classification from bullet wounds, and I believe that this is true today also. You will note that if Dr. Patton will exclude the shotgun wounds, which caused four out of his five deaths, his mortality from bullet wounds alone would be very low. The same is true of Dr. Howell's figures, in which the mortality from shotgun wounds is almost three times that of bullet wounds.

I do not believe that Dr. Patton's outline of the management of these bullet wounds leaves much cause for dissension. Perhaps the only matter for debate would be the question of colostomy. I have always felt that the right colon colostomy or the cecostomy is of questionable value except in cases where actual obstruction exists or is feared, and I would be glad if Dr. Patton would elaborate a little more on when he would do a right colon colostomy or would do a cecostomy.

Dr. T. B. Patton (Birmingham, Alabama): In answer to Dr. Guy's question, I can only say that we have not used cecostomy. We feel that when injury is sufficient to require the use of some form of decompression it should be in the form of an endeavor which will cause complete fecal diversion.

This at once brings up the controversial question concerning injuries to the cecum and the terminal ileum. As you saw from the slide, we have elected to resect these injuries. In so far as the performance of a colostomy is concerned, we perform colostomy where there has been gross fecal contamination, where there have been multiple wounds of the colon, or, as you saw in one case, with the early mortality, where a portion of the colon has been entirely blasted away.

It is necessary in some of these individuals to free up the flexure so that a colostomy can be established without tension.

THE METABOLIC EFFECTS OF TRAUMA TO DENERVATED TISSUE IN MAN*

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One by-product of the Second World War was the development of a solution of fructose satisfactory for intravenous administration. Usefulness of this new solution for investigation was rapidly realized. A comparison of the metabolism of intravenously administered fructose and glucose in man demonstrated definite differences between the two hexoses (22). In contrast to the marked alteration in the tolerance for glucose in diabetic patients, the tolerance for intravenous fructose was not found to differ in diabetic subjects and in normal man (3, 15). Since Claude Bernard's observation of an elevated blood glucose concentration following trauma, a number of metabolic defects have been described in association with injury (1). Among these is a diabetic like alteration in glucose metabolism (21). Because of the observed differences in glucose and fructose metabolism in diabetic patients it was suggested that fructose metabolism might escape the alteration that trauma was known to produce in glucose metabolism. A comparison of glucose and fructose metabolism following surgery in man demonstrated the anticipated diabetic type of glucose tolerance but no significant change was observed in fructose tolerance (5). Since the incorporation of glucose and fructose into the scheme of intermediary metabolism involves different pathways (2, 20), this result was interpreted to indicate that surgical trauma does not produce a uniform alteration of all metabolic pathways.

It has not been possible to investigate adequately the metabolic effects of trauma in acutely injured subjects because of the necessity for control studies. All previous studies with control observations have been conducted in surgical patients. In these studies, however, the metabolic effects of surgery could not be separated from those of the accompanying anesthesia. When carbohydrate metabolism was investigated during ether anesthesia without associated surgery in man, a definite difference was found from the metabolic changes following surgery with anesthesia (6).

A more desirable approach to this problem was to study carbohydrate metabolism following surgical trauma without anesthesia. An opportunity to perform

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such an investigation with preperative studies and necessary control of nutrition, infection and blood volume was provided by a group of paraplegic humans who required surgical repair of decubitus ulcers. Since the ulcers were located below the level of sensation, no anesthesia was required during surgery. This also afforded an opportunity to investigate the role of the nervous system in some of the biological alterations that follow trauma.

METHODS

The fifteen subjects in this study were hospitalized at Highland View Cuyahoga County Hospital for rehabilitation following traumatic transection of the spinal cord which had occurred several months to several years previously. All subjects had been hospitalized many weeks and were thoroughly acclimatized to the hospital, its personnel, and the daily physiotherapy activities. Diets were supplemented with oral vitamins, and in all instances the body weight was stable. During the postoperative period, care was taken to insure an adequate dietary intake by the use of intravenous alimentation when necessary. Many of the subjects had undergone previous surgery for decubiti or other complications, and several had participated in other investigative procedures. Each subject volunteered for the study which was conducted in the operating room to standardize as much as possible the effect of environment on the tests.

The surgical repair of the sacral decubitus ulcers was performed without anesthesia according to the technique previously described (11). Preoperative medication consisted of Meperadine (Demerol) 50 mgm. and Atropine sulphate 0.64 mgm. administered intramuscularly approximately one hour prior to surgery. These medications were not found to have a significant effect on the fasting level of the carbohydrate intermediaries studied. Occasionally it was necessary to supplement the initial dose of Meperadine to maintain satisfactory sedation. Blood loss was estimated by weighing sponges and tapes and the volume was replaced by transfusion.

A series of glucose, fructose, and lactate tolerance tests was performed. Seven subjects had glucose tolerance tests before and one or two days after surgery. In three of them a glucose tolerance test was also performed during operation. Five of these seven patients also had fructose tolerance tests performed before and after surgery. The patients thereby served as their own controls for comparison of the pre and postoperative tests, and for comparison of the metabolism of glucose with fructose. One of the patients included in the glucose series had a complete transection of the spinal cord at the C-5 level. His study was undertaken to investigate the role of the sympathetic nervous system in the metabolic response to trauma. Eight additional patients had three lactate tolerance tests which were performed the day before surgery, during operation, and on the first or second postoperative day. One patient was studied on three separate occasions.

Glucose or fructose was administered as a 10 per cent solution intravenously at the rate of 1 gm/kg. of body weight/hour. Sodium lactate was administered as a $\frac{1}{6}$ M solution at a rate of 8.2 ml. (0.15 gms.)/kg./hour. Samples of venous

TABLE I

Effect of Surgery Without Anesthesia on Glucose Tolerance

Patient	Time (min.)	Control				During Surgery				Post Surgery			
		G	PA	P	LA	G	PA	P	LA	G	PA	P	LA
D. K.	0	75	.72	3.6						91	.91	3.3	
	30	202	.75	3.0						232	.94	3.0	
	60	206	.91	3.6						374	1.28	2.8	
	90	174	.66	3.3						240	1.18	2.6	
	120	128	1.15	2.7						191	1.07	2.7	
	150	93	.85	3.0						124	1.28	2.8	
	180	65	.51	3.0						117	.48	2.9	
D. D.	0	86	.86	3.9						104	.80	3.7	
	30	186	.96	2.2						252	.75	3.5	
	60	254	1.44	2.3						276	1.42	3.4	
	90	126	.70	3.7						212	1.26	3.2	
	120	91	.96	1.3						154	.85	3.2	
	150	80	.75	1.5						122	.72	3.3	
	180	—	.35	4.3						101	.70	3.4	
V. M.	0	92	.72	3.5						111	.72	4.1	
	30	193	.62	3.5						230	.72	3.3	
	60	268	.80	3.0						338	.91	3.0	
	90	153	.64	3.0						185	.86	3.9	
	120	85	.27	2.7						139	.54	3.6	
	150	70	.38	2.9						115	.70	3.8	
	180	73	.51	2.6						108	.56	3.6	
D. B.	0	93	.94	3.2						118	.67	2.9	
	30	215	.85	3.1						256	1.26	2.6	
	60	291	1.21	2.8						334	1.36	2.6	
	90	166	.99	2.8						240	1.07	2.3	
	120	121	.85	2.3						194	1.36	2.3	
	150	82	.74	—						180	.99	2.5	
	180	71	.52	3.7						138	.69	—	
E. C. M.	F	—	—	—	—	82	.43	4.7	6.0	—	—	—	—
	0	81	.56	3.7	4.3	89	.56	4.8	3.8	98	.67	3.8	5.0
	30	164	.78	3.8	4.8	186	.67	4.6	4.2	233	.29	3.7	4.4
	60	194	.45	3.8	7.1	259	.78	4.1	4.3	301	.40	4.1	10.6
	90	124	.37	3.8	6.5	178	.59	3.8	3.8	260	.40	3.2	8.2
	120	75	.62	3.8	7.7	116	.62	4.3	6.3	194	.40	3.5	6.5
	150	58	.35	3.4	5.1	93	.48	3.8	7.1	133	.37	3.9	6.2
	180	63	.35	3.7	5.7	82	.48	4.0	2.7	106	.32	3.4	5.3
D. K.	F	—	—	—	—	81	.35	3.5	4.3	—	—	—	—
	0	73	.62	3.8	4.0	78	.27	3.6	3.5	93	.67	3.2	3.2
	30	185	.72	3.1	6.7	216	.40	3.1	4.4	208	.83	2.7	4.6
	60	202	.78	2.9	7.7	246	—	3.3	8.7	286	.88	2.5	5.3
	90	157	.80	2.8	4.2	—	—	—	—	233	.99	2.5	5.6
	120	111	.37	3.3	2.3	—	—	—	—	176	.75	2.4	4.8
	150	92	.56	3.1	2.7	—	—	—	—	136	.78	2.7	5.4
	180	69	.35	2.9	1.9	175	.35	—	—	108	.64	2.6	5.5

TABLE I—*Continued*

Patient	Time (min.)	Control				During Surgery				Post Surgery			
		G	PA	P	LA	G	PA	P	LA	G	PA	P	LA
W. S.	F	—	—	—	—	75	—	—	—	—	—	—	—
	0	72				88				71			
	30	167				208				216			
	60	243				259				275			
	90	188				210				224			
	120	139				162				134			
	150	105				103				81			
	180	77				87				62			

F = values obtained prior to surgery.

0 = values obtained prior to the start of glucose infusion.

G = glucose, PA = pyruvic acid, P = inorganic phosphorus, LA = lactic acid, all values in mg. %.

blood were withdrawn through an indwelling Cournand needle prior to the beginning of the infusion and every thirty minutes thereafter for a total of three hours. The blood samples were analyzed for glucose, fructose, pyruvic and lactic acids and serum inorganic phosphorus by methods described previously (6). On the day of surgery a sample of blood was obtained prior to starting the operation and the tolerance test was commenced one hour later.

RESULTS

The results of the series of glucose tolerance tests performed on seven patients one or two days before surgery, during operation without anesthesia (three patients) and on the first or second postoperative day are listed in Table I. Comparison of the pre-operative or control tests with the postoperative tests, with correction for the pre-infusion values of glucose, revealed a significant difference at all points studied (p less than 0.02) (Figure 1). The mean maximal rise in glucose above the pre-infusion level was 171 mg./100 ml. in the control tests and 213 mg./100 ml. in the postoperative tests ($p = 0.02$). The average assimilation coefficients following the cessation of glucose administration differed significantly from 0.0256 for the control tests to 0.0177 for the postoperative tests.

When the three tests performed during surgery were compared with their control tests a consistent alteration was found (Table Ia). The mean maximal rise in glucose above the pre infusion level was 137 mg./100 ml. in control tests, 169 mg./100 ml. during surgery and 224 mg./100 ml. in the postoperative tests. The post infusion assimilation coefficients (K) changed from 0.0228 for the control tests to 0.0178 for the tests during surgery and 0.0143 for the postoperative tests.

The results of the series of fructose tolerance tests performed on five subjects before and one or two days following operation without anesthesia are listed

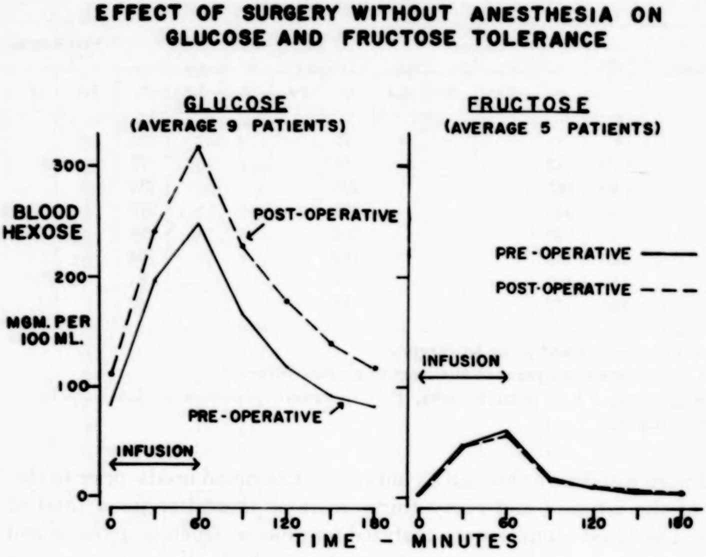

FIG. 1

TABLE Ia

Glucose Tolerance Before, During, and After Surgery Without Anesthesia

(Average of 3 patients)

Time (minutes)	30	60	90	120	150	180
Glucose mg/100 ml.*						
Pre-operation	96	137	81	33	9	−17
Operation	118	169	110†	50†	9†	−4
Post-operation	154	224	171	89	31	5

Glucose values are expressed in mg/100 ml. change from the pre-infusion levels.

* 10% Glucose 1 gm/kg I.V. in 60 minutes.

† Average of only 2 patients.

in Table II. No significant difference between the control and postoperative tests was demonstrated by application of the Fisher t test. The mean maximal rise in fructose above the pre infusion level was 60 mg./100 ml. in the control tests and 55 mg./100 ml. in the postoperative tests. Figure 1 illustrates the mean changes in the fructose values and contrasts these changes with those found for glucose. The marked difference between glucose and fructose tolerance found in the control tests has been noted and discussed previously (16).

Blood glucose rose during the administration of fructose. The mean maximal rise was 7 mg./100 ml. for the preoperative tests and 36 mg./100 ml. for the postoperative tests ($.05 > p > .02$). Figure 2 illustrates the significantly greater postoperative rise and delayed fall in glucose with the administration of the same amount of fructose as in the control tests.

TABLE II

Effect of Surgery Without Anesthesia on Fructose Tolerance

Patient	Time (min.)	Pre-operative					Postoperative				
		F	G	LA	PA	P	F	G	LA	PA	P
D. K.	0	9	74	4.0	.59	3.9	1.3	107	7.0	.86	3.13
	30	35.4	69	6.7	.78	3.4	50.8	113	25.8	1.42	2.46
	60	37.4	69	7.7	.96	3.6	68.2	137	32.2	1.95	2.28
	90	26.1	89	4.2	1.18	3.8	27.2	129	29.7	1.52	2.74
	120	13.2	69	2.3	.56	3.9	17.1	126	18.4	1.07	4.69
	150	6.2	64	2.7	.32	4.5	9.6	99	13.6	.51	2.36
	180	4.2	65	1.9	.43	3.8	6.7	103	12.6	.80	2.44
D. D.	0	1.5	84		1.23	4.3	1.8	90		.70	3.70
	30	54.	90		3.04	3.8	41.0	97		2.68	3.50
	60	62.	78		3.25	3.6	55.0	94		3.46	3.90
	90	18.	78		2.34	3.8	17.0	89		1.66	3.90
	120	8.	81		1.44	4.1	11.0	87		.98	3.90
	150	6.0	86		.75	4.7	10.0	88		.46	3.60
	180	3.	82		.64	2.9	5.0	89		.72	4.00
D. B.	0	2.4	79		.94	3.3	1.7	103	6.7	.82	2.9
	30	56.0	97		1.92	3.0	49.0	120	22.6	3.85	2.5
	60	70.0	97		2.03	3.9	58.0	167	27.6	4.20	2.9
	90	18.0	83		1.71	4.0	11.0	113	26.2	2.27	2.8
	120	10.0	93		1.34	3.5	8.0	105	20.0	1.34	3.8
	150	7.0	96		1.07	3.0	5.0	113	11.4	1.12	3.0
	180	7.0	91		.75	3.7	4.0	99	7.0	.83	3.9
V. M.	0	3.1	90		.78	3.8	3.9	86		.78	3.7
	30	59.0	108		1.20		52.0	123		1.04	1.8
	60	88.0	105		1.82	2.7	58.0	142		1.74	2.3
	90	23.0	104		1.12	3.7	16.0	137		1.12	3.7
	120	11.0	82		.80	2.9	9.0	142		.29	3.3
	150	6.0	83		.54	3.2	6.0	94		.32	2.5
	180	5.0	81		.40	3.4	5.0	106		.29	2.3
E. C. M.	0	1.6	97	21.6	.94	3.6	1.3	98	4.0	1.12	3.42
	30	36.3	97	26.0	.62	3.3	44.2	116	23.8	1.82	3.25
	60	50.2	93	35.2	.45	3.2	47.2	120	37.9	3.66	3.40
	90	9.8	85	14.7	.48	3.3	12.4	107	25.0	2.11	3.25
	120	4.0	84	7.4	.35	3.4	5.2	96	10.6	.64	3.18
	150	1.8	59	4.0	.35	3.3	2.6	92	6.4	1.26	3.25
	180	1.4	79	5.0	.51	3.4	1.9	91	2.4	.88	3.25

0 = Values obtained prior to the start of fructose infusion.

F = Fructose, G = Glucose, LA = Lactic acid, PA = Pyruvic acid, P = Inorganic phosphorus, all Values in mg/100 ml.

The infusion of either glucose or fructose caused an increase of blood pyruvic and lactic acids above the pre infusion levels (Table IIa). Following operation there was a greater rise in these acids with hexose infusion than in the control tests. In the case of glucose the postoperative rise in pyruvic acid was more

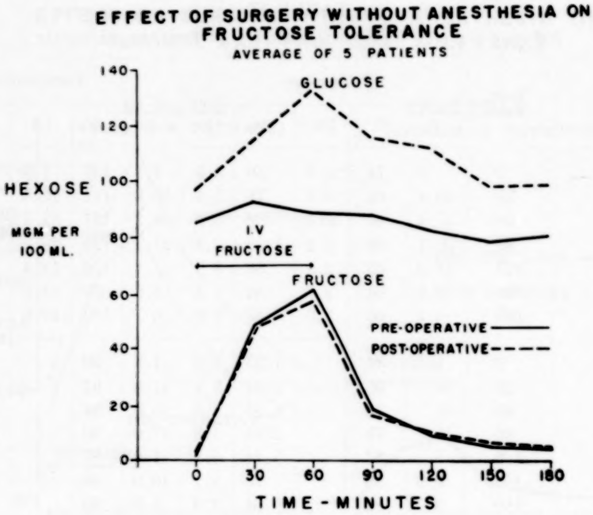

Fig. 2

TABLE IIa

Maximal Change in Pyruvic Acid, Lactic Acid, and Inorganic Phosphorus During One Hour of Hexose Administration

	Glucose, Mean of 6 Subjects	Fructose, Mean of 5 Subjects
Pyruvic acid (mg/100 ml.)	Maximal rise	
Pre-operation	.27	0.8
Post-operation	.3	2.1
	Mean of 2 Subjects	Mean of 3 Subjects
Lactic acid (mg/100 ml.)	Maximal rise	
Pre-operation	1.9	8.8
Post-operation	8.6	26.7
	Mean of 6 Subjects	Mean of 5 Subjects
Inorganic phosphorus (mg/100 ml.)	Maximal fall	
Pre-operation	0.8	0.6
Post-operation	0.5	0.7

sustained rather than higher (Figure 3). These differences could not be proved statistically significant in this limited number of cases. The greater rise of pyruvate and lactic acids with the preoperative infusion of fructose in comparison with glucose and the even greater rise in these acids with fructose infusion after operation is similar to our findings in surgical patients operated upon with general anesthesia.

Serum inorganic phosphorus fell with the administration of either glucose or fructose (Table IIa). Following operation the response of phosphorus to the infusion of fructose was unchanged in comparison to the preoperative studies, but there was less fall in phosphorus with glucose infusion after surgery. A similar decreased fall in phosphorus with glucose administration has been noted in diabetic patients (15), and in the postoperative patients with anesthesia (5).

The subject (D. D.) with a complete transection of the spinal cord at C-5 had a diabetic type of postoperative glucose tolerance (Table IIb). The coeffi-

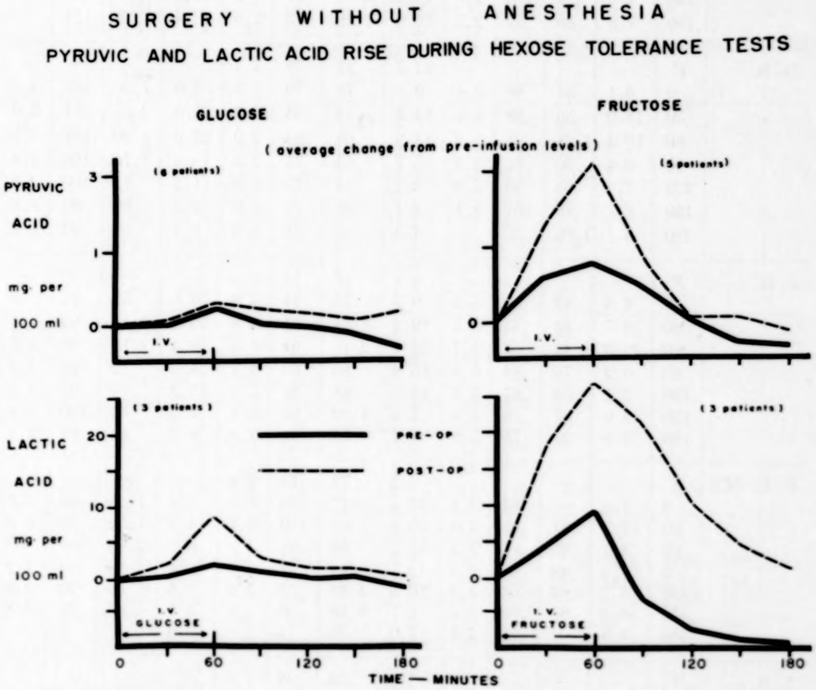

Fig. 3

TABLE IIb

Glucose Tolerance in a Patient With Transected Spinal Cord at C-5 Before and After Surgery Without Anesthesia

Time (minutes)	30	60	90	120	150	180
Glucose mg/100 ml.*						
Pre-operation	100	168	40	5	−6	—
Post-operation	148	172	108	50	18	3

Glucose values are expressed in mg/100 ml. change from the pre-infusion levels.

* 10% Glucose 1 gm/kg I.V. in 60 minutes.

TABLE III

Effect of Surgery Without Anesthesia on Lactate Tolerance

Patient	Time (min.)	Control				During Surgery				Post Surgery			
		LA	PA	G	P	LA	PA	G	P	LA	PA	G	P
R. B.	F	—	—	—	—	11.9	1.60	84	2.5	—	—	—	—
	0	8.3	1.26	102	3.0	8.1	1.55	83	2.5	15.9	1.52	116	2.9
	30	16.8	1.42	95	2.7	16.6	1.47	105	2.6	22.1	1.85	112	3.5
	60	19.9	1.36	102	2.8	24.1	1.79	117	2.7	28.0	1.96	116	2.9
	90	11.3	1.12	100	3.1	26.1	1.57	123	—	20.6	1.66	120	2.8
	120	8.2	.80	96	3.0	—	—	—	—	15.8	1.69	123	2.6
	150	7.4	.94	116	2.7	14.7	1.71	122	3.2	15.0	1.55	118	2.5
	180	7.5	.88	89	2.9	12.0	1.26	112	2.9	13.8	1.28	113	—
D. B.	F	—	—	—	—	11.3	.37	79	3.1	—	—	—	—
	0	5.1	.59	88	3.4	9.1	.78	79	3.3	9.0	1.36	104	3.4
	30	18.0	.56	88	3.2	14.5	.78	84	3.1	25.0	2.55	101	3.0
	60	19.4	1.28	91	3.2	14.9	1.08	84	2.9	25.0	1.90	101	4.0
	90	9.4	.96	91	3.2	3.7	.94	77	2.5	18.4	1.76	105	2.8
	120	7.4	.64	99	3.0	3.2	.94	78	3.0	11.5	.72	100	2.6
	150	6.8	.78	101	3.1	4.4	.59	71	3.9	6.5	.86	99	2.8
	180	5.7	1.04	97	—	4.3	.16	78	4.9	8.1	.56	92	4.2
J. K.	F	—	—	—	—	9.4	.88	91	3.4	—	—	—	—
	0	6.8	.43	91	3.5	9.3	.78	94	4.0	19.6	.51	92	3.7
	30	24.7	.56	85	3.4	19.2	1.34	95	3.6	15.2	1.34	92	—
	60	21.6	.43	93	3.7	24.4	2.19	91	3.4	19.4	1.18	93	3.5
	90	9.2	.70	85	3.8	15.6	.86	89	3.4	14.6	.32	90	3.5
	120	5.1	.59	87	3.5	12.6	.88	91	3.4	15.2	.37	92	3.5
	150	4.9	.67	78	3.6	7.3	1.02	93	3.4	7.5	.53	109	3.5
	180	2.8	.24	78	3.6	7.7	.51	94	3.9	8.1	.43	94	3.4
E. C. M.	F	—	—	—	—	6.2	.72	75	2.9	—	—	—	—
	0	7.6	—	83	3.1	12.4	.27	82	2.8	5.9	1.08	91	3.3
	30	12.1	.81	95	3.0	20.9	.67	110	3.4	14.0	1.52	90	3.6
	60	13.4	.99	89	3.3	21.5	.64	89	3.0	16.7	2.44	—	—
	90	7.0	.48	99	2.8	12.3	.43	81	3.0	8.8	.78	84	3.2
	120	5.7	.62	95	3.3	10.0	1.37	78	2.8	7.5	.86	73	3.3
	150	6.3	.67	94	3.5	7.7	1.15	76	2.7	5.4	.67	72	4.8
	180	5.9	—	91	2.5	7.0	.78	74	—	6.0	—	—	—
I. R.	F	—	—	—	—	7.1	.35	95	2.6	—	—	—	—
	0	4.0	.34	69	3.3	5.7	.30	104	2.6	6.8	.19	97	2.9
	30	16.0	.40	80	2.8	16.1	.40	100	2.8	35.0	.19	100	3.1
	60	20.0	.62	75	3.7	24.0	.27	97	2.6	23.7	.27	100	3.1
	90	11.3	.38	75	2.8	16.9	.19	97	2.7	21.3	.40	96	2.7
	120	6.6	.35	77	3.0	15.0	.40	115	3.0	7.6	.22	92	2.7
	150	6.1	.40	75	3.1	8.2	.35	99	3.0	6.8	.22	97	2.9
	180	5.4	.43	70	2.9	6.6	.40	94	3.0	—	.11	95	—
W. S.	F	—	—	—	—	3.1	.60	102	3.4	—	—	—	—
	0	8.4	.56	72	3.1	7.1	.10	—	3.1	5.8	.72	82	2.5
	30	12.2	.22	78	2.7	14.1	.57	87	3.0	11.3	.96	84	2.1
	60	14.4	.16	82	3.3	18.4	.48	90	3.1	13.9	.94	88	1.9
	90	9.1	.35	91	2.2	13.0	.48	69	3.1	7.6	1.14	83	2.2
	120	10.0	.64	78	2.9	11.5	.38	93	2.1	4.7	.75	78	2.2
	150	7.5	.64	75	2.6	7.2	.75	91	2.8	7.9	.72	84	2.2
	180	7.8	.54	66	2.7	6.1	.56	95	2.3	5.7	.59	96	1.5

TABLE III—*Continued*

Patient	Time (min.)	Control				During Surgery				Post Surgery			
		LA	PA	G	P	LA	PA	G	P	LA	PA	G	P
K. T.	F	—	—	—	—	5.5	.43	95	3.9				
	0	11.7	.43	76	4.3	9.3	.24	88	3.8				
	30	26.4	.35	63	5.4	23.7	.27	99	4.4				
	60	31.5	.38	70	4.4	32.5	.67	107	3.9				
	90	17.1	.64	83	3.5	21.9	.43	90	3.6				
	120	7.8	.38	73	3.7	16.6	.43	79	3.8				
	150	—	—	66	3.7	15.0	.32	77	3.6				
	180	—	—	81	4.0	—	—	112	4.2				
K. T.	F	—	—	—	—	8.0	.67	95	3.0				
	0	6.8	.94	92	3.0	12.5	.48	94	3.4				
	30	20.4	.81	74	3.0	24.0	1.44	103	3.0				
	60	30.2	1.35	76	3.4	33.7	2.57	110	2.7				
	90	9.8	.94	81	3.1	21.1	1.87	101	—				
	120	8.9	.67	87	2.9	21.1	1.58	90	2.8				
	150	7.8	.62	90	2.9	11.0	1.47	90	2.8				
	180	8.3	.67	96	—	11.1	1.07	84	—				
K. T.	F	—	—	—	—	8.7	.15	124	—				
	0	7.8	.24	88	—	8.8	.14	105	—				
	30	18.2	.38	87	—	33.5	.51	95	—				
	60	21.9	.38	88	—	24.2	.48	113	—				
	90	23.1	.27	84	—	13.7	.32	126	—				
	120	5.1	.22	86	—	13.2	.11	169	—				
	150	7.8	.46	83	—	5.9	.27	183	—				
	180	5.4	.24	70	—	9.7	.14	112	—				
L. M.	F	—	—	—	—	4.7	.06	75	—	—	—	—	—
	0	4.2	.86	150	—	9.3	.30	83	—	9.4	1.24	108	—
	30	15.0	.83	166	—	51.0	.70	103	—	18.1	1.74	114	—
	60	15.0	1.10	108	—	46.0	1.47	125	—	31.5	2.40	111	—
	90	24.0	1.23	95	—	21.2	1.36	124	—	20.7	1.76	120	—
	120	5.2	1.23	93	—	15.2	1.10	118	—	16.4	1.18	125	—
	150	4.4	.70	90	—	10.2	1.17	110	—	12.4	1.18	120	—
	180	5.0	.64	96	—	9.4	1.10	121	—	11.4	1.20	108	—

F = values obtained prior to surgery, 0 = values obtained prior to the start of lactate infusion.

LA = lactate, PA = pyruvic acid, G = glucose, P = inorganic phosphorus, all values in mg. %.

cient of assimilation (K) was 0.0577 in the control test and 0.0256 in the postoperative test. There was a slightly greater and more sustained rise in pyruvic acid and a decreased fall in serum inorganic phosphorus with the postoperative infusion of glucose (Table I).

The results of the lactate tolerance tests performed before, during and after surgery are listed in Table III. In comparison with the control tests there was a

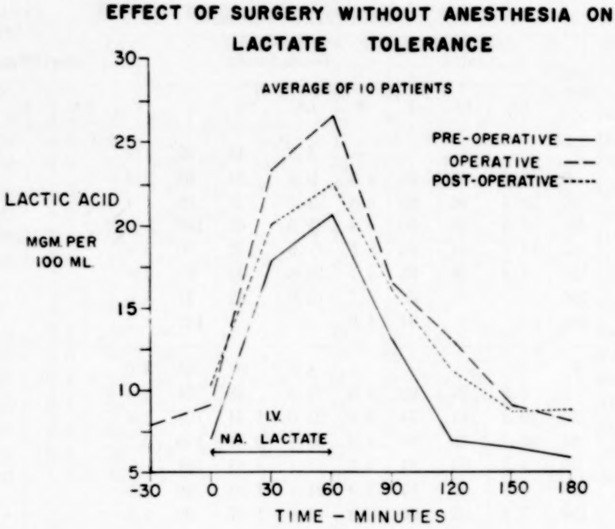

Fig. 4

consistently higher level of lactic acid during and following the administration of lactate in the tests performed during operation. The mean maximal rise above the pre infusion level was 14 mg./100 ml. in the control tests and 19 mg./100 ml. in the tests during surgery. The delayed fall in the lactate levels found during operation proved to be significantly different at 120 minutes ($.05 > p > .02$).

Although the postoperative levels of lactic acid were consistently higher than the controls in six out of seven subjects, no significant difference was found between these two tolerance tests if a correction was made for the higher fasting level of lactic acid in the postoperative period (Figure 4).

Infusion of $\frac{1}{6}$ M sodium lactate did not cause a significant change in glucose or inorganic phosphorus. Pyruvic acid rose an average of 0.2 mg./100 ml. with the infusion of lactate in the control tests. This mean rise was significantly increased both during surgery (0.7 mg./100 ml. $.05 > p > .02$) and during the first two postoperative days (0.76 mg./100 ml. $.02 > p > .01$).

DISCUSSION

The results have clearly demonstrated that in unanesthetized man, trauma to tissues without known nervous connection to the brain will cause alterations in intermediary carbohydrate metabolism. There was a significant alteration in the assimilation of glucose but no alteration in the assimilation of fructose in the same patients following surgery without anesthesia. The changes in glucose metabolism were found to start during operation and to persist at least forty-eight hours. Studies on three patients suggested that the alteration in glucose metabolism was more severe following surgery than during operation.

The total metabolism of fructose was not entirely unaffected. After fructose is phosphorylated, a certain portion is converted to glycogen, another moiety is converted to various intermediary compounds or catabolized completely to CO_2 and water and some is converted to glucose. This was reflected by a rise of glucose in the blood during the administration of fructose. During the postoperative tests, infusion of fructose caused a greater rise and a slower fall of blood glucose than in the preoperative tests. This may reflect a decreased ability to utilize glucose after surgical trauma or a greater rate of conversion of fructose to glucose. The discrepancy in the effect of trauma on glucose in comparison with fructose metabolism suggests inhibition of certain metabolic pathways. Since an alteration was also found in lactate metabolism, it is likely that more than one pathway is affected.

Previous study has shown that ether anesthesia produces a marked change in carbohydrate metabolism but the changes are largely dissipated within twenty-four hours (6). In contrast, trauma without associated anesthesia caused an abnormal glucose tolerance which persisted at least forty-eight hours. Also, the inorganic phosphorus rose during ether anesthesia despite the administration of either glucose or fructose. When trauma occurred without anesthesia, the inorganic phosphorus invariably fell with the administration of hexose although the magnitude of the postoperative fall was not as great with glucose as in the control tests. These observations support the conclusion that surgical trauma produces an alteration in carbohydrate metabolism different from that produced by anesthesia.

The increased rise of pyruvic and lactic acids with hexose infusion following trauma without anesthesia is consistent with our previous observation on patients who were subjected to extensive operations. These results differ from those found in patients who had less severe operations (herniorrhaphies) in which the postoperative rise in pyruvate with glucose infusion was less pronounced than in the control tests (5). The difference in the pyruvate response may reflect the reaction to different degrees of trauma. However, a decreased fall in serum inorganic phosphorus with glucose infusion was found after both herniorrhaphies and more extensive operations.

The mechanisms whereby the metabolic effects of trauma are mediated remain to be elucidated. There is evidence to suggest that adrenal cortical steroids are involved. There is an increased output of adrenal steroids after trauma (12, 13, 17, 19). The known effects of hydrocortisone on carbohydrate metabolism such as production of an abnormal glucose tolerance without alteration in fructose tolerance, and an increased rise of pyruvic and lactic acids with glucose infusion are very similar to the changes observed in the present study (9, 10). Craig has found that patients with steroid diabetes (Cushing's syndrome) have an even greater rise of pyruvic and lactic acids when fructose is administered (4). Also patients with Cushing's syndrome have the high fasting concentration and excessive accumulations of lactic acid following infusions of sodium lactate similar to the results of the lactate tests performed during trauma (9). Finally, Krieger found an increased urinary excretion of 17-hydroxysteroids following surgery performed in the denervated area of human paraplegics (14).

While this does not prove that an increased output of adrenal steroids occurs following trauma in these patients, it strongly suggests an increase does occur despite the sectioned spinal cord.

Careful study in anesthetized dogs, however, indicates that an intact afferent nervous system is necessary for the production of an adrenal cortical response to peripheral trauma (7). Since the present study demonstrates that an alteration in carbohydrate metabolism occurs after trauma to tissues without an intact afferent nervous system, other means for stimulation of release of ACTH must be considered (18). Psychic stimulus in the unanesthetized subjects, liberation of endotoxin from chronically infected tissue in the operative area, the very extensive surgical procedure or inadequate replacement of blood loss, many have triggered release of ACTH in these patients. It is possible that no change occurred in the adrenal secretion of hydrocortisone. Instead, the rate of removal of hydrocortisone may have been delayed following trauma of this magnitude.

An increased activity of the sympathetic nervous system may have been responsible for the observed metabolic changes rather than an alteration in hydrocortisone secretion or blood level (8). This seems unlikely, however, in view of the definite alteration in glucose metabolism that occurred following trauma in a patient (D. D.) with a spinal cord transected above the level of any known sympathetic outflow (C-5).

SUMMARY

The effect of surgery without anesthesia on the metabolism of glucose, fructose, and lactate was studied in patients who underwent operative repair of decubiti below the level of spinal cord transection. The metabolism of glucose and lactate was altered while that of fructose was unchanged; the changes were different from those produced by anesthesia alone.

It was concluded that:

1. Surgical trauma apparently affects only certain metabolic pathways since fructose metabolism was unchanged.
2. An intact afferent nervous system is not essential for the observed metabolic response to trauma since the surgical repair was carried out below the level of cord transection. Other possible mechanisms are discussed.

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REFERENCES

1. Bernard, C. Des conditions physiologiques à remplier pour constater la presence du sucre dans le sang. Compt. Rend. Acad. d. Sci., **82:** 1405–1410, 1876.
2. Cori, C. F. and Cori, G. T. Fate of glucose and other sugars in the eviscerated animal. Proc. Soc. Exper. Biol. & Med., **26:** 432, 1928–29 (Feb. 29, 1929).
3. Craig, J. W., Drucker, W. R., Miller, M., Owens, J. E., Woodward, H., Brofman, B. and Pritchard, W. H. Metabolism of fructose by the liver of diabetic and non-diabetic subjects. Proc. Soc. Exper. Biol. & Med., **78:** 698–702, 1951.
4. Craig, J. W., Drucker, W. R. and Miller, M. Unpublished observations.
5. Drucker, W. R., Miller, M., Craig, J., Jefferies, W. M., Levey, S. and Abbott,

W. A comparison of the effect of operation on glucose and fructose metabolism. Surg. Forum, **3:** 548–555, 1952.

6. Drucker, W. R., Costley, C., Stults, R., Holden, W. D., Craig, J., Miller, M., Hofmann, N. and Woodward, H. Studies of carbohydrate metabolism during ether anesthesia. I. Effect of ether on glucose and fructose metabolism. Metabolism, **8:** 827–846, 1959.
7. Egdahl, R. H. Pituitary-adrenal response following trauma to the isolated leg. Surgery **46:** 9–21, 1959.
8. Halme, A., Pekkarinen, A. and Turunen, M. On the excretion of noradrenaline, adrenaline, 17-hydroxycorticosteroids, and 17-ketosteroids during the postoperative stage. Acta endocrinol., Copenhagen, **24:** suppl. 32: 1–52, 1957.
9. Henneman, D. H. and Bunker, J. P. The pattern of intermediary carbohydrate metabolism in Cushing's syndrome. Am. J. Med., **23:** 34–45, 1957.
10. Hennes, A. R., Wajchenberg, B. L., Fajans, S. S. and Conn, J. W. The effect of adrenal steroids on blood levels of pyruvic and alpha-ketoglutaric acid in normal subjects. Metabolism, **6:** 339–345, 1957.
11. Hubay, C. A., Kiehn, C. C. and Drucker, W. R. Surgical management of decubitus ulcers in the post-traumatic patient. Am. J. Surg., **93:** 705–713, 1957.
12. Hume, D. M., Nelson, D. H. and Miller, D. W. Blood and urinary 17-hydroxycorticosteroids in patients with severe burns. Ann. Surg., **143:** 316–329, 1956.
13. Krieger, H., Abbott, W. E., Levey, S. and Holden, W. D. Re-evaluation of the role of the adrenal and other factors in the metabolic response to surgery. Surgery, **44:** 138–148, 1958.
14. Krieger, H., Levey, S., Drucker, W. R. and Abbott, W. E. A study of the metabolic response to surgery in paraplegics. Surg. Forum **11:** 475–477, 1960.
15. Miller, M., Drucker, W. R., Owens, J. E., Craig, J. W. and Woodward, H. Metabolism of intravenous fructose and glucose in normal and diabetic subjects. J. Clin. Investigation, **31:** 115–125, 1952.
16. Miller, M., Craig, J. W., Drucker, W. R. and Woodward, H. Jr. The metabolism of fructose in man. Yale J. Biol. & Med., **29:** 335–360, 1956.
17. Sayers, G. The adrenal cortex and homeostasis. Physiol. Rev., **30:** 241–320, 1950.
18. Sayers, G. and Royce, P. C. Regulation of the secretory activity of the adrenal cortex. Clinical Endocrinology I, Section V, Chapter I, pp. 323–334, Grune and Stratton, Inc., New York, 1960.
19. Selye, H. The general adaptation syndrome and the diseases of adaption. J. Clin. Endocrinol., **6:** 117–230, 1946.
20. Slein, M. W., Cori, G. T. and Cori, C. F. A comparative study of hexokinase from yeast and animal tissues. J. Biol. Chem. **186:** 763–780, 1950.
21. Thomsen, V. Studies of trauma and carbohydrate metabolism with special reference to the existence of traumatic diabetes. Acta med. scandinav., suppl. **91:** 1–416, 1938.
22. Weichselbaum, T. E., Elman, R. and Lund, R. H. Comparative utilization of fructose and glucose given intravenously. Proc. Soc. Exper. Biol. & Med., **75:** 816–818, 1950.

DISCUSSION

Dr. Morris J. Fogelman (Dallas, Texas): I believe it was another Frenchman, Descartes, who said "even that which is true can sometimes be proven." I am sure Dr. Drucker, who has been interested in the field of metabolic derangements for some years, finds himself in a similar rather philosophic dilemma in attempting to relate some of the changes which occur after injuries in man.

In essence, he has demonstrated that following injury a patient remains much like a diabetic, in that the utilization of glucose compared to fructose is altered. In addition he has included evidence to indicate that this is somewhat apart from sympathetic pathways and possibly unrelated to anesthesia.

I am sure we are all aware of the fact that great caution must be exercised in interpretation of these data. For instance, I should like to see him take the same patients to the operating room with the same preoperative preparation, et cetera, and do everything but the operation, and see what the metabolic response might be.

In addition, previous data indicate that large-scale transfusions produce a similar metabolic response, so I would like to know how much blood was given to these patients.

Extending these data to the more practical side, I wonder if Dr. Drucker is ready to say that maybe the administration of glucose to postoperative patients is just a bad habit, like many other bad habits we have accumulated, and maybe all postoperative patients should receive fructose. I wonder, Bill, if you are ready to declare this, and if you are not ready, why aren't you?

Finally, I wonder whether he might think that the utilization of fructose might provide a better protein sparing effect compared to glucose. Some years ago the late Bob Elman indicated after four or five days of glucose therapy a patient simulated a diabetic, and to utilize glucose he advocated that small amounts of insulin be given as a supplement to therapy. Does Dr. Drucker advocate this now?

I want to thank Dr. Drucker for the privilege of reading his paper. I am delighted to state that it is a good piece of work, but I also want to know the answers to my questions.

Dr. William R. Drucker (Cleveland, Ohio) (Closing): I want to thank Dr. Fogelman for his kind and very provocative remarks. Obviously, some of his questions cannot be answered completely.

We were aware, of course, of the psychic trauma that an operation is likely to cause. It is common knowledge that a diabetic can be put into acidosis by psychic trauma, We attempted to control this by having all patients, first of all, volunteers; secondly, all procedures were carried out in the same environment. The preoperative and postoperative tests and the ones during surgery were all conducted in the operating room, the same operating room where they had their surgery done.

We did operate on patients without operating them, in this sense. Many of these patients that I discussed with you have been part of our study on ether anesthesia. These patients were taken to the operating room, and instead of having surgery were anesthetized with ether. This was done with their consent and knowledge. However, the metabolic changes produced during ether, while quite severe, were all gone by the next day. All I can suggest is that there is sufficient psychic stimulus in knowing you are going to be anesthetized that, if this were a real factor, one might expect to have the same metabolic changes lasting forty-eight hours, as we found in these patients. These metabolic changes lasted much longer than the changes found during ether anesthesia. Also, the effect on inorganic phosphorus was different with anesthesia than with surgery.

In so far as the effect of volume, there is some question whether an increased volume has anything to do with ACTH release. Possibly with hypervolemia, the attendant changes in osmolarity, the problems of tissue perfusion because of cardiovascular changes, could release ACTH. This is unanswered. We don't know, and we have had no studies on the effect of hypervolemia on carbohydrate metabolism.

In so far as hypovolemia is concerned, there is an extensive literature on this. We have contributed some of it ourselves. We do know that with shock, hypovolemia, there are marked metabolic changes very similar to the ones we described here. As blood is given back, these changes all come back to normal, even though the blood replacement is not sufficiently adequate and the animal goes on and dies.

One thing in this line I think is very interesting. We did a study in which, instead of returning blood, we returned dextran. The only purpose of dextran was that it was a non-red cell containing fluid. We found that the metabolic improvement was equally as good as if we had given back blood. In other words, return of volume seems to be vital to improvement of metabolism, but replacement of so-called oxygen carrying capacity is not so vital, and this can be carried to a hematocrit down low in the teens. This is a side issue, but it does answer to some extent this problem of volume.

As for the practical point, I purposely avoided this because I think an investigator frequently compromises his position as an investigator when he becomes allied with one side of a highly debatable therapeutic problem. I personally use fructose in extensive cases, but I am not mad at anyone who does not use it. I think it has academic advantages. I am not too sure from a very practical standpoint it has much to offer over glucose.

So far as the protein sparing effect, Dr. Elman has done some work on this, also Dr. William Abbott; I think fructose has a better protein sparing effect, but in the aggregate, except in the very severely malnourished or the extensively ill patient who is going to require intravenous alimentation for a long period of time, I can't really urge that fructose be employed.

VASCULAR REPLACEMENT IN GROSSLY CONTAMINATED WOUNDS:*

An Experimental Study Comparing Formalin Preserved Homografts and Plastic Prosthesis

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INTRODUCTION

In military or traumatic surgery a vascular graft or prosthesis must frequently be placed in a contaminated wound. Subsequent bacterial infection often causes failure of the replacement procedure. Thrombosis or vessel rupture may result in spite of local and systemic antibiotic therapy (5). Several clinical and experimental studies dealing with this problem have been published, but a satisfactory solution has not been found (2, 3, 4, 7–9, 13).

Foster, Berzins and Scott (4) showed that 80 per cent of freeze-dried, ethylene oxide sterilized arterial homografts disrupted in the presence of bacterial infection. Either the homograft perforated or the anastomotic sutures pulled out of the graft. Synthetic prostheses of nylon or teflon did not rupture, but in 27 per cent of the animals anastomotic sutures pulled out of the host vessel. Thrombosis and widespread peritonitis were less frequent complications but occurred more often in animals receiving synthetic grafts.

In cases in which infection develops around a homograft, rupture with fatal hemorrhage is probably the result of digestion of the graft by proteolytic enzymes produced by the offending organisms. Plastic prostheses are resistant to proteolysis, but as foreign bodies, they tend to potentiate the infection. This may contribute to thrombosis of the graft or even worse, extension of the infection to the prosthetic-aortic suture line with resultant disruption.

It occurred to us that formalin preserved homografts might improve results as vascular replacement substances in grossly contaminated and infected wounds. The formalin could inhibit bacterial growth and inactivate proteolytic enzymes (1, 11, 14). Such a graft might resist infection without eliciting the foreign body reaction associated with plastic prostheses. This hypothesis was tested in dogs.

MATERIALS AND METHODS

The experiment was divided into three groups:

Group I. Aortic homografts preserved in acid, buffered, 4% formalin solution

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* The opinions or assertions contained herein are the private ones of the authors and are not to be construed as official or reflecting the views of the Navy Department or the naval service at large.

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and implanted in a clean surgical field—a control group. Eight animals comprised this group.

Group II. Aortic homografts preserved in acid, buffered formalin solution and implanted in a field contaminated with feces. This group consisted of twenty animals.

Group III. Crimped teflon prostheses implanted in a field contaminated with feces. This group consisted of twenty animals.

A solution of 4% formalin was prepared and adjusted with calcium carbonate to pH 5.6 (12). Abdominal aortic homografts were obtained from sacrificed mongrel dogs, cleaned of all areolar tissue and placed in the solution of formalin. The vessel segments remained in this fixative for intervals varying from forty-eight hours to six months prior to being implanted in the contaminated animals. The solution was checked at various intervals, and it was demonstrated that the pH remained between 5.4 and 5.8 throughout the course of the experiment. Each aortic segment was washed by immersion in sterile saline for at least one hour prior to implantation.

Young, adult, mongrel dogs weighing 11.5 to 30 kilograms were anesthetized with intravenous pentobarbital sodium. Under sterile conditions laparotomy was performed. The peritoneum overlying the aorta was incised, care being taken to prepare margins adequate to effect a water-tight closure at the conclusion of the procedure. Either a formalin fixed aortic homograft, or a crimped teflon prosthesis, each approximately 5 cm. in length, was inserted into the distal aorta 1 cm. or more above the trifurcation. An effort was made to select replacements approaching the same diameter as that of the host aorta. Anastomoses were performed with continuous over and over sutures of linear 5-0 polyethylene (Dermalene).

Prior to laparotomy, feces from each dog in the contaminated groups (II and III) was obtained by digital rectal examination. A ten per cent saline suspension of feces was made and strained through a gauze sponge to remove large particulate matter. Aliquots of these suspensions were cultured and found to contain the coliform group of organisms and hemolytic staphlococcus aureus. After careful closure of the peritoneum overlying the aortic replacement, 1 cc. of the fecal suspension was injected through a small bore needle around the vessel. Early in the experiment 4 cc. of the contaminating media were used, but due to an extremely high incidence of fatal peritonitis, this dosage was reduced to 1 cc.

All animals received 1.5 million units of penicillin and 0.5 gms. of streptomycin daily for the six days after the operative procedure. In several instances, antibiotics were continued longer than the six-day period in an effort to avert overwhelming infection.

Animals were followed closely after the operative procedures. Femoral pulses were carefully observed and the animal was immediately sacrificed if these pulses disappeared. Control animals were sacrificed 8 to 12 months postoperatively. Contaminated animals were examined at autopsy 6 months after surgery. All animals dying prematurely underwent immediate postmortem examination to determine the cause of death.

At laparotomy the retroperitoneal area was examined for residual pus. The

TABLE I

Sterile Formalin Preserved Homografts

Dog	Outside Diameter Aorta (cm)	Outside Diameter Graft (cm)	Follow-Up Period (months)	Cause of Death	Graft Condition
1	1.0	1.0	8	Sacrifice	Patent
2	0.9	0.8	8	Sacrifice	Occluded
3	1.0	0.9	12	Sacrifice	Patent
4	1.3	1.0	12	Sacrifice	Occluded
5	1.2	1.1	11	Sacrifice	Patent
6	1.0	1.0	11	Unknown	Patent
7	1.1	1.1	13	Sacrifice	Patent
8	1.2	1.2	13	Sacrifice	Patent

6 Patent
2 Occluded

TABLE II

Contaminated Formalin Preserved Homografts

Dog	Outside Diameter Aorta (cm)	Outside Diameter Graft (cm)	Follow-Up Period (months)	Cause of Death	Graft Condition
1	0.7	0.7	2 days	Sepsis	Patent
2	0.7	0.7	3 days	Sepsis	Occluded
3	0.6	0.6	14 days	Sepsis	Patent
4	0.8	0.8	6	Sacrifice	Patent
5	1.0	1.0	6	Sacrifice	Patent
6	1.1	0.9	14 days	Sepsis	Occluded
7	0.9	0.9	1	Hemorrhage	Ruptured
8	1.0	1.0	6	Sacrifice	Patent
9	1.2	1.0	6	Sacrifice	Patent
10	0.9	0.9	6	Sacrifice	Patent
11	0.9	0.9	17 days	Sepsis	Occluded
12	0.8	0.8	6	Sacrifice	Patent
13	0.9	1.1	6	Sacrifice	Patent
14	0.9	0.8	6	Living and well	Pulses 4 plus
15	0.7	0.7	6	Living and well	Pulses 4 plus
16	0.9	0.9	6	Sacrifice	Patent
17	1.0	0.9	6	Living and well	Pulses 4 plus
18	1.0	0.8	6	Living and well	Pulses 4 plus
19	0.9	0.8	6	Sacrifice	Patent
20	0.9	0.9	6	Living and well	Pulses 4 plus

6 Deaths (all related to infection)
3 Grafts occluded
1 Graft ruptured
14 Survivors—all grafts patent

gross configuration of the abdominal aorta with its contained replacement was described in detail. The outside diameters of the host aorta and vascular replacement were measured. After sacrifice, the host aorta and substitute were removed in toto. The specimen was then photographed and cut for microscopic examination.

Five animals from each of the two contaminated groups (II and III) have not been sacrificed. These animals will be followed to compare the effectiveness of the two types of vascular replacements over a long period of time.

RESULTS

Six of eight control animals had a functioning homograft when sacrificed one year postoperatively. Two of these six homografts were uniformly dilated, but no localized aneurysms were found. Four of eight animals formed firm plaques within the homograft wall. In all control animals with patent grafts the intima was intact, smooth and glistening.

Six animals in each of the contaminated groups died prematurely. For five animals in Group II and two animals in Group III, death was due to generalized

TABLE III

Contaminated Teflon Prostheses

Dogs	Outside Diameter Aorta (cm)	Outside Diameter Prosthesis	Follow-Up Period (months)	Cause of Death	Condition of Prosthesis
1	0.9	1.0	6	Sacrifice	Patent
2	1.0	1.0	6	Sacrifice	Patent
3	0.9	1.0	11 days	Sepsis	Occluded
4	1.0	1.0	6	Sacrifice	Patent
5	1.0	1.0	6	Sacrifice	Patent
6	1.0	1.0	2 days	Intussusception	Occluded
7	1.0	1.0	0	Anesthesia	Patent
8	0.9	1.0	6	Sacrifice	Patent
9	1.0	1.0	33 days	Distemper	Patent
10	0.8	1.0	6	Sacrifice	Patent
11	1.0	1.0	6	Sacrifice	Patent
12	1.2	1.0	19 days	Hemorrhage	Rupture—distal aorta
13	0.9	1.0	4 days	Sepsis	Occluded
14	0.9	1.0	6	Sacrifice	Patent
15	0.8	1.0	6	Sacrifice	Patent
16	1.0	1.0	6	Living and well	Pulses 4 plus
17	1.3	1.0	6	Living and well	Pulses 4 plus
18	1.0	1.0	6	Living and well	Pulses 4 plus
19	0.9	1.0	6	Living and well	Pulses 4 plus
20	1.3	1.0	6	Living and well	Pulses 4 plus

6 Deaths (3 related to infection)
3 Prostheses occluded
1 Aorta ruptured
14 Survivors—all prostheses patent

peritonitis or septicemia. The other three deaths in Group III were from unrelated causes—intussusception, anesthesia and distemper. Three of the Group II dogs which died from sepsis had received 4 cc. of the fecal suspension, a dose which produced an overwhelming infection. The remaining animals received 1 cc. of the contaminant material. As judged by postoperative lethargy, toxicity and fever, this latter dose was a satisfactory bacterial challenge.

One animal in each contaminated group died of hemorrhage. A formalin

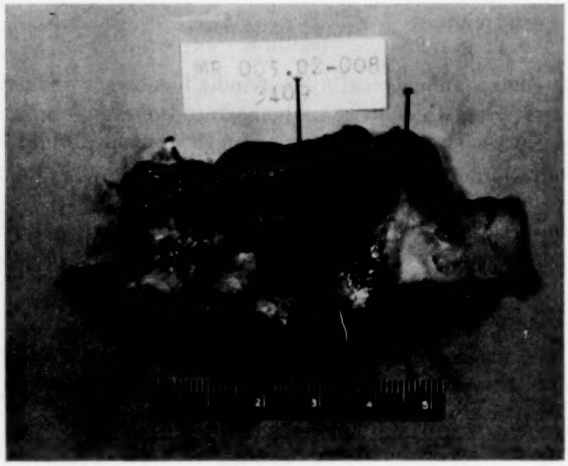
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Fig. 1. This photograph shows the single graft rupture of Group II

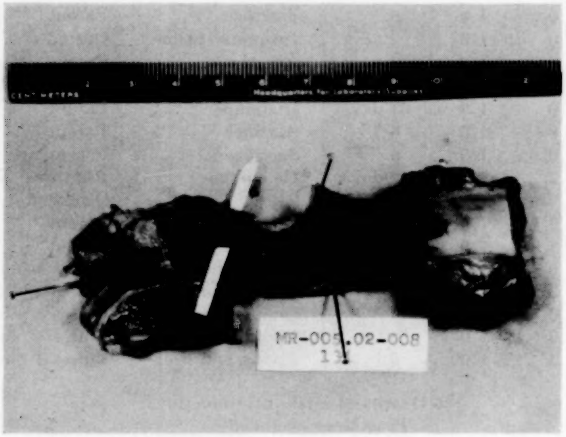
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Fig. 2. Photograph of teflon prosthesis with rupture of host aorta 3 mm, distal to the anastomosis.

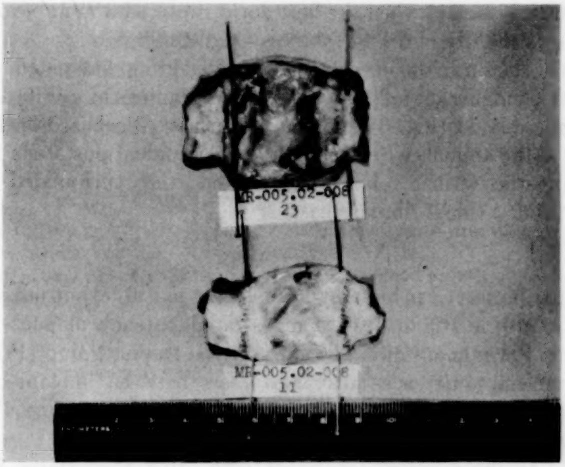

Fig. 3. Homografts from the contaminated Group (II). Mild uniform dilation is seen in the upper specimen. Note the well healed anastomoses and the intact neo-intimas of both specimens.

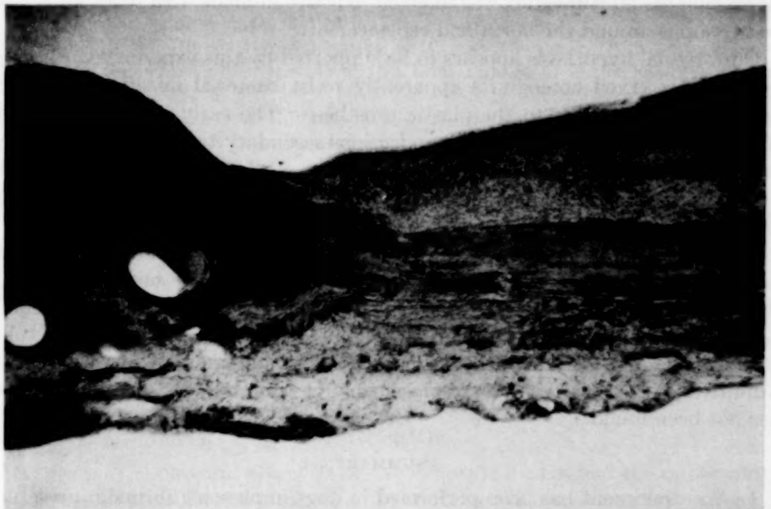

Fig. 4. Photomicrograph (× 29.5) of formalin preserved homograft from Group II removed six months following implantation. This section is taken through the proximal anastomotic line. Note the thick neo-intima, residual elements of the graft media and fibrous host contributed adventitia (H&E stain).

preserved homograft ruptured 1 cm. distal to the proximal anastomosis (Fig. 1). A teflon prosthesis failed when the host aorta ruptured 3 mm. beyond the distal anastomosis at the site of a large abscess (Fig. 2).

Fourteen of the survivors in each contaminated group had patent replacements at six months, judging by full femoral pulses or findings at sacrifice. Four homografts became dilated (Fig. 3), but only one showed localized aneurysmal dilation. None of the animals with homografts had residual pus at six months. Two synthetic prostheses in Group III, however, were surrounded by purulent material within a thick, fibrous mass.

DISCUSSION

Homografts preserved in buffered formalin are passable, but not ideal vascular substitutes. Guthrie (6) in 1919 demonstrated patency of such a homograft eleven years after implantation. Recently Payne and his group (10) were unable to find significant differences after two years between implanted homografts stored in nutrient media or in acid buffered formalin. In time all homografts showed degenerative changes.

Compared to the reported experience with other homografts, formalin preserved homografts apparently have an increased resistance to disruption in the presence of infection. This resistance may be due to inactivation of bacterial proteolytic enzymes by the formaldehyde. In addition, formalin preserved homografts show less tendency than plastic prosthetics to perpetuate infection. At six months no homograft was infected, but two animals with teflon prostheses had free pus around the aorta and replacement.

Our original hypothesis appears to be supported by this experiment. Although formalin preserved homografts apparently resist bacterial infection, they were not uniformly superior to the plastic prostheses. The early complications were similar in both groups, but late complications secondary to degenerative changes may be higher in the homograft animals. Thus, we do not recommend formalin preserved homografts in preference to plastic prosthetics in contaminated wounds when the latter are available.

Under unusual circumstances in war or during major civilian disasters, plastic prostheses may not be readily obtainable. Formalin fixed homografts might then serve well as emergency vascular replacements in contaminated wounds. No special equipment or techniques are required. Vessel segments may be taken at routine autopsies and may be used after several months of preservation. Admittedly, the ideal vascular replacement for contaminated or infected cases has not been found.

SUMMARY

1. An experiment has been performed in dogs implanting formalin preserved, arterial homografts and crimped teflon prostheses in operative fields contaminated with feces.

2. Although the formalin preserved homografts appear to be more resistant to disruption in the presence of infection than homografts preserved by other

methods, functional results were not superior to those obtained with the plastic prostheses.

3. Formalin preserved homografts are not recommended for use in contaminated or infected fields when plastic prostheses are available.

4. The availability of formalin preserved homografts for emergency vascular replacement in war or during major civilian disasters has been discussed.

REFERENCES

1. Al-Shamma, A., Pfaff, W. W., Stemmer, E. A. and Allen J. G. Changes in human citrated plasma produced by 60°C. heat exposure for 10 hours and the protective action of formaldehyde and dextrose. Surg. Forum **9:** 91–95, 1958.
2. Claytor, H., Birch, L., Cardwell, E. S. and Zimmerman, S. L. Suture-line rupture of nylon aortic bifurcation graft into the small bowel. A.M.A. Arch. Surg., **73:** 947–950, 1956.
3. Ekman, C. A. and Scott, H. W. Jr. Influence of experimental staphlococcic infections on arterial anastomoses and grafts. Bull. Soc. Int. Chir. **19:** 133, 1960.
4. Foster, J. H., Berzins, T., Scott, H. W., Jr. An experimental study of arterial replacement in the presence of bacterial infection. Surg., Gynec. & Obst., **108:** 141–148, 1959.
5. Foster, J. H., Lance, E. M., Scott, H. W., Jr. Experience with ethylene oxide treated freeze-dry arterial homografts in 110 consecutive patients. Ann. Surg., **148:** 230–238, 1958.
6. Guthrie, C. C. End-results of arterial restitution with devitalized tissue. J.A.M.A. **73:** 186, 1919.
7. Harrison, J. H. Influence of infection on homografts and synthetic (Teflon) grafts. A.M.A. Arch. Surg., **76:** 67–73, 1958.
8. Humphries, A. W., deWolfe, V. G. and LeFevre, F. A. Analysis of 120 consecutive cases of major arterial grafts. J.A.M.A., **161:** 953–956, 1956.
9. Jamplis, R. W., Rugtiv, G. W., Burkman, V. and Cressman, R. D. Resection of ruptured abdominal aortic aneurysm with fatal rupture of aortic homograft. Ann. Surg., **147:** 393–398, 1958.
10. Payne, W. S., Edwards, J. E., Grindlay, J. H. and Ellis, F. H., Jr. The ultimate fate of implanted aortic homografts preserved in acid-buffered formalin. A.M.A. Arch. Surg., **80:** 61–70, 1960.
11. Pfaff, W. W., Stemmer, E. A., Al-Shamma, A., Dawson, D., and Allen, J. G. The treatment of pooled human plasma with formaldehyde at 60°C. for 10 hours. Surg. Forum **9:** 95-98, 1958.
12. Peirce, E. C., II, Rheinlander, H. F., Moritz, A. R., Gross, R. E., and Merrill, K., Jr. Transplantation of aortic segments fixed in 4 percent neutral formalin. Am. J. Surg., **78:** 314–323, 1949.
13. Schramel, R. J., Creech, O., Jr. Effects of infection and exposure on synthetic arterial prostheses. A.M.A. Arch. Surg., **78:** 271–279, 1959.
14. Walker, J. F. *Formaldehyde*. p. 220. Rheinhold Publishing Corporation, 330 West Forty-Second Street, New York, U. S. A.

DISCUSSION

Dr. Jere W. Lord, Jr. (New York, New York): I have had the opportunity of studying Captain Brown's paper, and I must say that it is not only a beautifully conceived study but it also has been carefully executed, and his conclusions suggest that one can have a good deal of optimism in the repair of wounds by means of grafts and prostheses, particularly formalin grafts, when the wound is badly contaminated.

I am afraid I have to take a pessimistic view of this, based on evidence I will present in a moment, this in spite of the wonderful development of homografts, the development of the prostheses, beginning with Dr. Blakemore's Vinyon N cloth and now with woven Teflon and the crimped knitted Dacron of De Bakey, and in spite of the wonderful development of the broad spectrum of antibiotics. All of these have failed to accomplish what we would like in grossly infected wounds.

The evidence is as follows: In 1942 Dr. Blakemore and I tried out a similar study using autogenous vein grafts in the femoral arteries of dogs, employing a contaminated wound which had been made twenty-four hours earlier. We were studying not only the use of chemotherapy in the form of sulfathiazole and sulfanilamide, but also comparing the vitallium tube technique of joining the ends of the vein graft to the divided artery as compared with the suture technique as outlined by Carrel.

Briefly, our results showed that in grossly infected wounds nothing worked. In lesser contaminated non-purulent wounds the vitallium tube technique was sounder than the suture technique, as the latter resulted in more frequent aneurysm formation and dehiscence of the anastomoses. The vein grafts seemed to be ideal, however, as a substitute.

Clinically Dr. Peter Stone and I have had poor results on our service and in practice. I would like to cite these briefly.

The first case is that of a long autogenous vein graft, 45 cm., extending from the common femoral to the popliteal artery to overcome an obstruction on an atherosclerotic basis. This man did well for several weeks and then developed an obviously infected hematoma. This was a contamination that occurred in the operating room. About two months postoperatively, after draining the hematoma everything seemed to be going well when he suddenly had a gross hemorrhage, the wound was explored, and there was a perforation in the midportion of the vein graft.

The wound was cleaned up, another vein graft inserted in the defect, with the contaminated part of it removed. This worked well for seven days and again ruptured. The third operation consisted of tying off the vein graft and the man was restored to his original status, unimproved. This was an instance of contamination with Staphylococcus aureus.

The second patient is one that I did, putting in a flat Dacron prosthesis for a similar type obstruction in the superficial femoral artery. The prosthesis thrombosed, hematoma developed, and within a few months after the initial operation infection was evident, the prosthesis became exposed, and about two weeks later a massive hemorrhage occurred from the proximal anastomosis. It was necessary to ligate the external iliac artery. The leg survived but the patient was restored to his original condition.

The third patient was an individual with an atherosclerotic popliteal aneurysm who had a primary excision of the aneurism and the insertion of a woven Teflon prosthesis. Everything seemed to go well for three months, when he suddenly developed a hematoma in the popliteal area. Exploration revealed a small opening between the proximal anastomosis and prosthesis in the popliteal artery. The wound appeared clean and a culture was taken. It showed Staphylococcus albus hemolyticus. The patient had a ligation of the popliteal artery above and below. He has a good leg, but with intermittent claudication.

The final case is one which Dr. Stone had, wherein the patient had chemotherapeutic treatment for an advanced carcinoma of the pelvic organs. A polyethylene catheter was inserted in another hospital to treat it with chemotherapeutic drugs through the common iliac artery. The catheter had been passed up the superficial femoral artery. Ten days of successive treatment were applied and the catheter removed. Two weeks later a massive hemorrhage appeared in the groin. She was admitted to the University Hospital where Dr. Stone operated upon her and found a grossly infected wound.

There was a perforation of the common femoral artery due to the infection. A good deal of pus was present. The slide shows a De Bakey Dacron prosthesis in place extending from the external iliac artery to the superficial femoral artery. It could be seen to pulsate well and it worked for seven days when massive hemorrhage occurred from a dehiscence of the proximal anastomosis. The artery was ligated and the prosthesis removed. The leg survived and the wound was later closed.

In conclusion, I believe we can say that in grossly infected wounds nothing is going to work, and the patient's best interests can be served by ligating the artery above and below the point of injury and making use of good conservative measures to bring about improvement in the collateral circulation.

In minimally contaminated wounds, with the use of antibiotics and good surgical technique, prostheses and vein grafts will work in a high percentage of cases. The formalin graft, I think, will have to be studied further in human material but, certainly in the experimental work of Captain Brown, it looks most favorable.

Dr. D. W. Gordon Murray (Toronto, Ontario): I was much interested in these very interesting presentations, especially that of Dr. Brown describing replacement of vessels in the presence of infection. My interest in this dates to the '30's when, in working on heparin and blood vessel grafts, I did a group in which we added infection to the wounds in the presence of vein grafts in arteries.

It is true these grafts were placed in the carotids and not in the aorta, but I believe that a vein graft is adequate in every artery except the aorta; and, more than that, it is always available. You have the locker right with you.

In a group of animals I put in vein grafts in the carotid and then infected the wounds from the laboratory floor. These wounds suppurated; they granulated and finally healed, and the grafts remained patent.

That probably differs from the experiments described by Dr. Brown. His were open suppurating wounds preceding the grafting. My experiment was one in which infection was added at the time of the operation, and perhaps that does make a great difference. I have talked about vein grafts with infection on former occasions, and my suggestion would be to explore it further.

Dr. R. B. Brown (Bethesda, Maryland) (closing): I wish to thank Dr. Lord and Dr. Murray for their discussions.

I think it should be re-emphasized that there is a difference between the experimental condition that I was reporting and the conditions referred to by both the discussers. We chose contaminated wounds, because part of our premise was that perhaps formalin homografts would show less tendency to promote and potentiate infection in the contaminated wound than the plastic protheses. These were not established infections, and I can't agree more heartily that the chance for successful vascular replacement in a wound which is already the site of an infection is quite grim.

Just one further comment: Our clinical experience with staphylococcal infections in wounds, the site of vascular replacements, has been a little better than Dr. Lord's. We have had too many—four such—but in three of them we have obtained healing. Although the follow-up period has not been in terms of many years, we hope that they will stay healed. But this was one of the reasons for the study. We feel that even after months, and perhaps years, infection may persist around one of these plastic protheses and relight and cause difficulty.

EDITORIAL

THE COMPLETE SURGEON OF TRAUMA

Current trends towards subdivision of an injured person into as many watertight compartments as he has systems are equally apparent in modern methods of undergraduate instruction, residency training, and the treatment of trauma. In theory these are intended to insure that each of his injuries will receive the most expert care available. But the care of injuries by a "committee of specialists" incurs the grave risk that no one takes care of the patient.

The injured person is inevitably beset by a welter of adverse intangible forces which often exert profound influences against recovery. The purely scientific surgeon will dismiss their manifestations as, "psychosomatic"—which is merely a refuge of the diagnostically destitute. The complete surgeon recognizes them as normal reactions to emotional stress and their management as his obligation equally as much as the control of hemorrhage or the realignment of a broken bone.

He appreciates the personality of his injured patient to be a very delicate mechanism which remains adjusted to its environment only by virtue of a buffer system of hopes and fears, joys and sorrows, aims and frustrations, triumphs and disappointments; and that maintenance of these emotional "electrolytes" in balance is an essential part of his job. He is aware that satisfactory balance will depend upon protection of his patient from the harmful effects of anxiety, suggestion, litigation, and iatrogenic factors—that failure in this will invite a dismal result despite perfection in the mechanical aspects of treatment—and that an ounce of prevention will be worth many pounds of cure.

Anxiety is an inevitable concomitant of injury. Chronic nightmares filled with fears of complications, failure of recovery, loss of earning capacity, and hardship in the home are common. These are seldom recognized by the surgeon whose horizon of interest is limited to the perimeter of the scientific problem at hand. The complete surgeon knows that uncertainty is mother to anxiety, and will take steps to dispel these specters whether or not they are apparent on the surface.

He knows that chronic neglected anxiety must spawn compensatory emotions which often are sublimated into an exaggeration of existing symptoms, an elaboration of symptoms without organic basis, or gross personality changes. Above all, he is aware that while the products of anxiety never conform to as consistent a pattern as the physical results of trauma, yet they reflect as innate a response to injury as inflammation and repair.

Suggestion is a potent source of emotional upset in the healthy. How much more potent will be the results of suggestion upon an injured person by his surgeon—in conversation, in some teaching exercise, or during the course of ward rounds? Harmful suggestions may be made consciously or through carelessness, but sometimes are deliberate and inspired by motives unbecoming a surgeon.

It is neither necessary, wise, nor completely honest to tell a laborer with a fractured transverse process, "your back is broken"—to tell one who has failed to recover under another's care, "you have had the wrong treatment"—or to tell the man with a bulging abdominal incision, "you couldn't have been sewn up properly." It is far better to tell the person who has had a knee operation that some postoperative numbness is the rule than to say, "the nerve to your knee was cut." To tell a patient, "this is the worst case I have ever seen," merely reflects a psychological quirk in the surgeon but may very well produce another in the patient. To tell a patient nothing is worst of all, for he may interpret this as news which is too bad to be told. These are examples of what led Sir Arthur Hurst to coin the term "iatrogenic," which he applied to disorders induced in a patient by autosuggestion, based on the surgeon's examination, manner, or discussion. Fully as much as physical factors these are the things of which catastrophies are made.

Litigation, which is firmly entrenched in our society, often impedes recovery. The primary desire of every injured person is to recover as quickly as possible, but often almost from the start he is besieged by a sequence of psychological forces, each tending to submerge this desire under a flood of avarice.

The first is often some magnification of the injury by his surgeon. In rapid succession come suggestions from friends, relatives, attorneys, union representatives, and others that he also must magnify his troubles in order to recover as large a settlement as possible. Before long the intransigence of some insurance adjuster may transform these incubating suggestions into a firm conviction that persisting disability and exaggerated symptoms are necessary to a defense of his legal position—and he is then well on the way to becoming a chronic emotional cripple. Only his surgeon has the ability, obligation, and opportunity to control and maintain in proper perspective these mischievous intangible forces.

The surgeon of trauma will never be complete until he can refute Plato's 2,000-year-old indictment, "This is the greatest error in the treatment of human sickness, that there are physicians for the body and physicians for the soul, yet the two are one and indivisible."

Harrison L. McLaughlin, M.D.

JOINT ACTION PROGRAM

of the

AMERICAN COLLEGE OF SURGEONS

AMERICAN ASSOCIATION FOR THE SURGERY OF TRAUMA

NATIONAL SAFETY COUNCIL

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SURGEONS HELP PREVENT TRAFFIC TRAUMA: THE JOINT ACTION PROGRAM

G. C. STEWART

Executive Vice President, National Safety Council

The medical profession can claim a large share of the credit for the steadily declining traffic accident death rate in recent years. Many victims who formerly would have swelled the fatality statistics now live, thanks to improved techniques of surgery and medical treatment. However, there are many important areas in which the medical profession and the safety professionals can successfully cooperate in preventing the accidents from occurring in the first place. This is being increasingly recognized, and several important developments in the last five years give evidence of this.

JOINT ACTION PROGRAM

In 1956, the late Dr. Charles G. Johnston, then President, American Association for the Surgery of Trauma, and Dr. I. S. Ravdin, Chairman, Board of Regents, American College of Surgeons, expressed their views to me concerning a joint accident prevention effort. The surgeons outlined the history and interests of the three organizations and strongly made the point that the medical people had taken too little interest in preventing trauma and the safety people had taken too little interest in the human salvage operations of the doctors. "The problems of prevention and restoration are interlocking."

Drs. Johnston and Ravdin suggested that a joint committee of the three organizations be formed "with the purpose of exploring the possibility and methods whereby a more effective attack may be made against this problem through the mutual cooperation of our most active lay and surgical groups interested in this problem."

A Joint Policy Committee was formed under the chairmanship of Dr. George M. Wheatley, a member of the Executive Committee of the Board of Directors of the National Safety Council. This committee developed a Joint Program for execution at the national level and at the local level through joint action of local safety councils and the local committees of the two surgical organizations. This program included six major objectives:

1. Education of the public in accident prevention and handling of the injured.
2. Establishment of local committees of the American College of Surgeons and National Safety Council, together with other interested surgeons, safety engineers, and public officials to formulate safety plans.
3. Registration of unusual cases of injury.
4. Investigations of emergency care of traffic injuries.
5. Model legislation to require adequate training in first aid and transportation of the injured for ambulance attendants, policemen, and firemen.

6. Cooperation in producing and improving training materials and instructional aids dealing with problems in handling the injured.

To aid in implementing the program, two planning memoranda were prepared for the guidance of persons at the local level. It was emphasized that none of the suggested projects to implement the six objectives were crash programs but were in the nature of long-range activities.

TRANSPORTATION OF THE INJURED

In 1958, the committee undertook an investigation and project to improve the transportation of injured persons. Three main problem areas were identified:

1. Traffic regulation of casualty-carrying vehicles.
2. Training and competency of ambulance personnel.
3. Equipment of casualty-carrying vehicles.

The Annual Traffic Inventory, administered by the National Safety Council, was used in 1958 to gather information on these subjects from 865 cities. Analysis of this information revealed:

1. A grossly inadequate proportion of ambulances and dual-purpose patrol cars available for transportation of the injured.
2. That a "helper" accompanies the driver in the majority of cities.
3. Data on equipment show a great deal to be desired.
4. Accepting the reported figures at face value, a significant number of untrained personnel are handling traffic casualties in the cities comprising this survey.
5. In approximately 95 per cent of the cities, special privileges were accorded casualty-carrying vehicles to travel at greater than legal speeds and to disregard traffic signals in emergencies.

As a result of this survey, a joint committee under the chairmanship of Dr. Oscar P. Hampton, Jr., American College of Surgeons, was appointed to draft a model ordinance regulating the equipment and traffic control of ambulances and the training of personnel. The model ordinance this committee developed provides for requiring ambulance drivers to complete a course of training equivalent to the advanced American Red Cross course in first aid; requiring all vehicles used as ambulances to carry full equipment; requiring periodic inspection of vehicles by health officers; and requiring ambulances to conform to all laws and regulations governing ordinary traffic.

A strong case has been made for the last point—that of requiring ambulances to adhere to all laws and regulations governing ordinary traffic. In the report on the Transportation of the Injured survey prepared by Dr. Hampton, it was stated that:

> "The Committee on Trauma holds that ambulance travel on city streets and highways should be regulated by the same laws, rules and regulations which regulate other traffic. Speed is, for practical purposes, seldom if ever a factor in the preservation of a life; and speeding ambulances have occasioned more traffic deaths than lives saved by rushing pell-mell to medical facilities. All cities and states should regulate the speed and manner of driving of ambu-

lances and other casualty-carrying vehicles by laws which carry stringent penalties for violation."

Writing for the August, 1958, issue of the National Safety Council's *Traffic Safety* magazine, Drs. George J. Curry and Sydney N. Lyttle, Fellows of the American College of Surgeons, cite the experience of Flint, Michigan which supports the above position:

"In this series of 2,500 consecutive ambulance runs, haste in transporting the injured was unnecessary in 98.2 per cent. There would have been no difference in the outcome of 2,455 patients had they been transported according to the standard traffic regulations.

"In 1.8 per cent expeditious handling was considered necessary, but a speeding ambulance could have increased the severity of the injuries."

THE PRESIDENT'S COMMITTEE

The Action Program of the President's Committee for Traffic Safety is the master plan under which all safety organizations work. It deals with all of the various functions—accident records, driver licensing, enforcement, education, etc.—and was first developed as a result of the White House Conference on Highway Safety in 1946.

In 1960 and early 1961 the Action Program was extensively updated. At that time, because of the interest in transportation of the injured, Mr. William Randolph Hearst, chairman of the President's Committee, appointed a committee under the chairmanship of Dr. Wheatley to develop material on the subject for inclusion in the Action Program.

The Committee submitted a draft report in March containing the main points of the model ordinance that had been developed and the original survey report. This was subsequently revised and shortened and submitted to the Advisory Council of the President's Committee at its meeting of January 12–13, 1961.

The Advisory Council accepted the following parts of the report:

"Every jurisdiction should have adequate laws and ordinances governing care and transportation of persons injured in vehicle accidents.

"Under provisions of the Uniform Vehicle Code, authorized emergency vehicles are permitted to proceed past stop signs, exceed speed limits, and generally assume privileges not granted to drivers of ordinary vehicles. But, in the words of the Code, 'The foregoing Provisions shall not relieve the driver of an authorized emergency vehicle from the duty to drive with due regard for the safety of all persons, nor shall such provisions protect the driver from the consequences of his reckless disregard for the safety of others.'

"A joint committee of the American College of Surgeons, the American Association for the Surgery of Trauma, and the National Safety Council has reported that there are comparatively few times when the use of excessive speed by an ambulance driver is either necessary or desirable. They agree further that *reckless* ambulance driving is more likely to kill people than to save lives."

Because it is a rule that nothing in the Action Program shall conflict with the

Uniform Vehicle Code, the Advisory Council felt that it would not be proper at this time to recommend that ambulances be required to adhere to all rules governing ordinary traffic, but rather the matter should be referred to the National Committee on Uniform Traffic Laws and Ordinances for study with the view of possible revision of the Uniform Vehicle Code.

Because the Advisory Council felt that the subject of Transportation of the Injured was only one aspect of traffic safety involving the medical profession, it passed the following resolution:

> "That by Committee action the President's Committee for Traffic Safety develop an additional section to the Action Program entitled "Health and Medical Care" and that the section on Emergency Care and Transportation of the Injured . . . be adopted as an annex to the Action Program."

ANNUAL TRAFFIC INVENTORY

Special Section

In 1960, another development occurred that should provide a great deal of information for the Action Program section mentioned above. With the cooperation and advice of the U. S. Public Health Service and the Association of State and Territorial Health Officers, the National Safety Council developed a special questionnaire to be prepared by the chief public health officer in each state. This is primarily for the purpose of finding out what the health departments in each state do in traffic safety and to what extent other departments utilize the special knowledge and skills of the medical profession in such areas as driver licensing, traffic law enforcement, education, research and statistics, and improving care of the injured.

This information will be the subject of a special report. This activity should also do much to stimulate more interest and cooperation between state health departments and those departments concerned with traffic safety and management.

FUTURE PLANS

The Policy Committee of the Joint Action Program held an all-day meeting on April 28, 1961, at which past accomplishments were reviewed and plans for future joint programs were made. Indicative of the broad field in which the three organizations have common interests is the list of some of the subjects discussed: the Uniform Vehicle Code and Model Traffic Ordinance, a survey of ambulance accidents, seat belts, more cooperation at the community level, burns, hospital emergency departments, action at the accident scene, and alcohol and drugs.

COMPARISON OF THE WOUNDING CHARACTERISTICS OF SOME COMMONLY ENCOUNTERED BULLETS

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Chief, Trauma Investigation Branch
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Most of the principles used in the management of wounds due to missiles have emerged from wartime experiences. In the endeavor to effect the overnight metamorphosis of a civilian physician into a military surgeon, it has been found necessary to set up dogmatic rules of wound management that will result in the greatest good to the greatest number. Some of these rules are invariably true, and universally applicable, such as the statement that wounds containing large amounts of unremoved necrotic tissue should not be sutured. However there is a point at which the experienced surgeon wonders to what extent ALL of the rules developed in wartime are universally applicable to missile wounds encountered in civil practice.

An obvious difference is that in peacetime (except in civil disaster) the same surgeon normally follows each patient for the duration of treatment, and close and continued observation is possible. The most important consideration, however, is whether there is a difference in the type of wound produced by the missiles commonly encountered in peacetime as compared with the higher velocity bullets, and the irregular shell fragments, of wartime.

The chief question which occurs is the extent to which radical debridement is indicated. In war surgery this has been accepted as a "must" in high velocity missile wounds of large muscle groups (e.g. thigh, gluteal area). Yet most surgeons have seen peacetime bullet wounds in these regions that healed without complications when for some reason little or no debridement was done.

This subject was considered 200 years ago by John Hunter (8) when he served as a military surgeon in the British expedition against Bellisle in 1761. He stated that in the treatment of gun-shot wounds the surgeons of his day "have made no discrimination between one gun-shot wound and another; this would appear to have arisen . . . from an opinion that gun-shot wounds have something peculiar

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to them, and of course are different from all other wounds . . . I own that I do not see any peculiarity . . . few gun-shot wounds are alike and therefore the same practice can not apply to all." Further, "There will be a great difference should the instrument (wounding agent) be a ball passing with great velocity, for in this case a slough will be produced. But if it should pass with little velocity, then there will be less sloughing and the parts will in some degree heal by first intention." Hunter also observed that the formation of slough "does not always take place equally in every gun-shot wound, nor in every part of the same wound; and the difference commonly arises from the variety in the velocity of the body projected; for we find in many cases where the ball has passed with little velocity, which is often the case with balls, even at their entrance, but most commonly at the part last wounded by the ball, that the wounds are often healed by the first intention." He mentioned that with the higher velocity missiles, a wound "is often not completely understood at first, for it is at first in many cases impossible to know what parts are killed, whether bone, tendon, or soft part, till the deadened part has separated, which often makes it a much more complicated wound than at first was known or imagined; for it very often happens that some viscus, or a part of a large artery, or even a bone, has been killed by the blow, which does not show itself till the slough comes away."

At that time the treatment of these wounds consisted, according to Hunter, of "opening the external orifice" of all gun-shot wounds made by musket balls as soon as the patient was received. It is probably not unreasonable to equate the amount of "slough" mentioned by Hunter with the extent of devitalized tissue, although infection was probably a contributing factor.

Hunter's observations were based, as are most of the modern discussions of this topic, on clinical observations made during wartime. This type of study has many variables hindering quantitative evaluation of the actual effect of various missiles and the extent of differences between them. In World War II surgeons were still trying to relate the surgical treatment required to the type of projectile causing the wound. There are several sources of confusion in the evaluation of wartime clinical studies on the extent of surgical therapy needed in missile wounds:

(1) Time post-injury when patients were received. For instance Crile (3) in 1943 described good results obtained with minimum surgical therapy in a group of patients with bullet wounds seen *11–13 days* post-injury. Possibly he would be unaware of those dying BEFORE reaching his hospital.

(2) Definition of "debridement." For example a group of patients described by Ferguson (4) in 1943 as healing well WITHOUT debridement, actually had treatment that other surgeons have defined as *adequate debridement*.

(3) A third source of confusion in evaluating wartime clinical studies is that often wounds from very different types of projectiles are included together. For instance, *shell fragments* as encountered in World War II and the Korean conflict can have velocities ranging from 6000 ft/sec to as low as 300 ft/sec. Their shape is irregular and their weights vary from about 1 grain to over a pound. The *bullets* used in World War II and Korea did not exceed a muzzle

velocity of about 2800 ft/sec. Of course this velocity decreases greatly with distance from the target.

The present study has utilized the facilities of a well-equipped biophysics laboratory to permit observations under more controlled circumstances. This laboratory has been engaged full time in wound ballistics research for the past 15 years, as a direct lineal descendant of the Yale and Princeton groups of World War II (Harvey (6)) which in turn had extended the earlier work of Callender (2), and Wilson (14).

In this paper, discussion will be limited to bullet wounds of muscle and soft tissue of the thigh, in which an attempt was made to avoid bony and major arterial damage. The purpose is to answer in an objective manner the question, "To what extent does the type of bullet influence the severity of the wound to be expected and therefore possibly affect the extent of surgery required?" It must be noted that the present study concerns bullets only, and does not include shell fragments. The latter have a more variable effect, and are not commonly encountered in peacetime. It must be noted also that this study involves only extremity wounds, where the question of extent of debridement required is most frequently raised.

PROCEDURE

Seven types of bullets were used: two for rifles and five for pistols (Fig. 1). Characteristics of these projectiles are shown in Table 1. The caliber .45 pistol rounds and the caliber .30 military rifle rounds were manufactured at Frankford Arsenal. The caliber .22 round was the Remington standard velocity Kleanbore .22 Long Rifle cartridge. The remainder of the pistol bullets were Winchester rounds. None of the bullets used was a soft point or hollow point bullet intended to deform in the target. None of the bullets deformed in striking the gelatin or goat targets.

The calibers .22, .30 and .45 rounds were fired from Mann barrels, using a Universal receiver on a fixed mount. The other pistol bullets were fired from pistols borrowed from the Baltimore Police Crime Laboratory (courtesy of Captain Anthony F. Nelligan). The four pistols used were: a caliber .32 Smith and Wesson six-shot revolver with a $3\frac{3}{8}$ inch long barrel, a caliber .38 Harrington and Richardson five-shot revolver with a $3\frac{3}{8}$ inch long barrel, a caliber .32 Colt automatic pistol with a $3\frac{3}{4}$ inch long barrel, and a caliber .380 Colt automatic pistol with a $3\frac{3}{4}$ inch long barrel. All the handguns were fired from fixed mounts.

The targets used were castrated male Angora goats, closely clipped in the areas to be wounded, and blocks of 20% gelatin (by weight). The goats averaged 39 kg in weight with a range of 36 kg to 42 kg. The gelatin targets were rectangular blocks, 38.0 cm by 12.6 cm by 15.1 cm in size and were used at a temperature of 10°C.

All targets were located 15 feet from the muzzle of the gun being used.

The various bullets were fired into the gelatin blocks. Gelatin in this high a concentration is a tough, elastic material which simulates muscle tissue reasonably well for ballistics purposes. Being transluscent, it permits the path of the

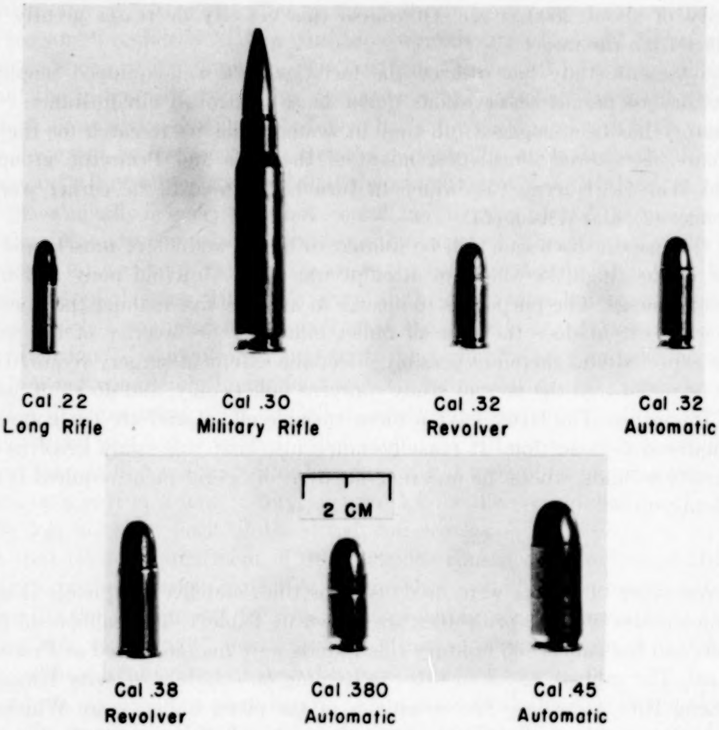

Cal .22
Long Rifle
Cal .30
Military Rifle
Cal .32
Revolver
Cal .32
Automatic
2 CM
Cal .38
Revolver
Cal .380
Automatic
Cal .45
Automatic

FIG. 1. Rifle and pistol bullets used in present study

TABLE 1

Characteristics of Bullets Used

Bullet	Weight	Average Velocity	Slug or Core	Jacket
	grains	*ft/sec*		
Caliber .22 ball, long rifle	40	1206	Lead	None
Caliber .30 ball, military	147	2844	Mild steel	Steel, gilding metal
Caliber .32 ball, revolver W32-SWP	85	613	Lead	None
Caliber .32 ball, pistol, automatic W32AP	71	863	Lead	Gilding metal
Caliber .38 ball, revolver W38-SWP	145	605	Lead	None
Caliber .380 ball, pistol, automatic W380AP	95	882	Lead	Gilding metal
Caliber .45 ball, pistol, M1911	229	846	Lead	Steel, gilding metal

missile to be recorded photographically. High speed motion pictures (15,000 to 16,000 frames per second) were taken of the trajectories of the projectiles through the gelatin tissue models.

The films were examined frame by frame and the relationship of the instantaneous distances penetrated by the bullets into the gelatin to the time after impact was determined. The first derivative of this relationship is the velocity, so that the velocity of the bullet at any distance of instantaneous penetration into the gelatin can be readily calculated. When the velocity of the projectile and its weight are known, the remaining kinetic energy of the bullet at any point can also be calculated. The first derivative of the relationship between the remaining kinetic energies and the instantaneous distances penetrated is expressed in terms of units of energy per unit distance of penetration. In this paper the metric system is used and the units are joules per centimeter. The joules per centimeter are plotted against the distance of instantaneous penetration of the projectiles, as in figures 2 and 3. The energy absorbed by any portion of the gelatin target from the bullet can be determined by measuring the area under the curve for that portion of the target.

The goats were anesthetized by intravenous administration of sodium pentobarbital. The hind limbs were fastened together and the bullet was aimed to traverse both, so as to approximate more closely the greater muscle mass of the human. The skin was not cleansed or prepared other than by the clipping of the hair. The animals were shot in a right-left direction through the muscles of the thighs so as to avoid injury to the large blood vessels and the femurs.

There was minimum of three goats for each bullet study group. On the third or fourth day after wounding, the wound tract of one of the group was measured for diameters of wounds and thicknesses of tissues perforated, and samples were taken for histologic study. A second goat from the group was given 24 ml of 10% Disulphine Blue V.N. dye (Imperial Chemical Industries Ltd.) intravenously before a similar examination of the wound tract on the fourth postwounding day. This dye is said to stain only viable tissue, and has been recommended for diagnosis of extent of third degree burns, and of non-viable bowel in cases of strangulation, etc. (1, 9). A third goat of each group was returned to the laboratory for close observation for at least 24 hours, after which it was placed in a nearby pen where it was examined daily by a veterinarian. After three or four weeks, the wound tracts of these animals were studied. No dye was used in these animals because it was considered that by this time any nonviable tissue should be clinically apparent.

It is important to note that this study as reported here enables qualitative comparison among the classes of bullets represented, with particular reference to comparing the effects of the higher velocity with the lower velocity bullets. It is not intended as a quantitative report on the full characteristics of each of the bullets under all circumstances. There is in this laboratory an extensive body of precise data concerning the effects of various missiles, some of which information will be included in the discussion. The relatively few goats reported on in this paper merely serve as examples of the type of results to be expected.

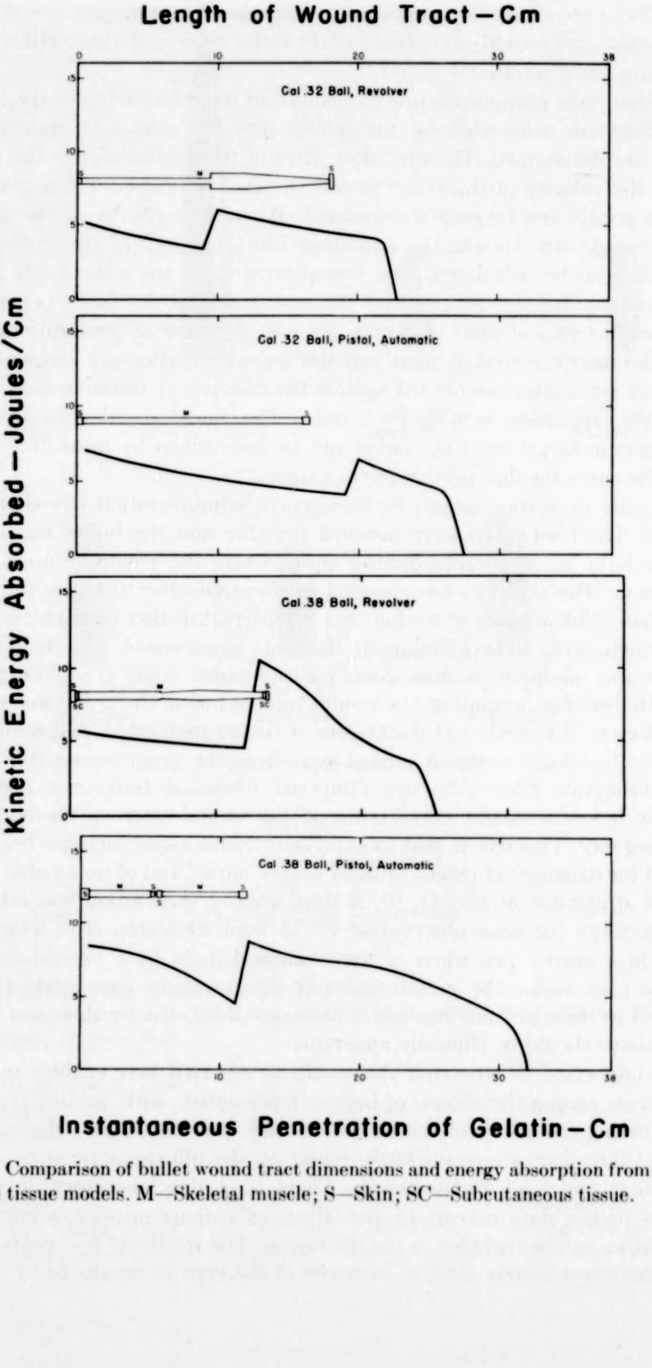


FIG. 2. Comparison of bullet wound tract dimensions and energy absorption from bullets by gelatin tissue models. M—Skeletal muscle; S—Skin; SC—Subcutaneous tissue.

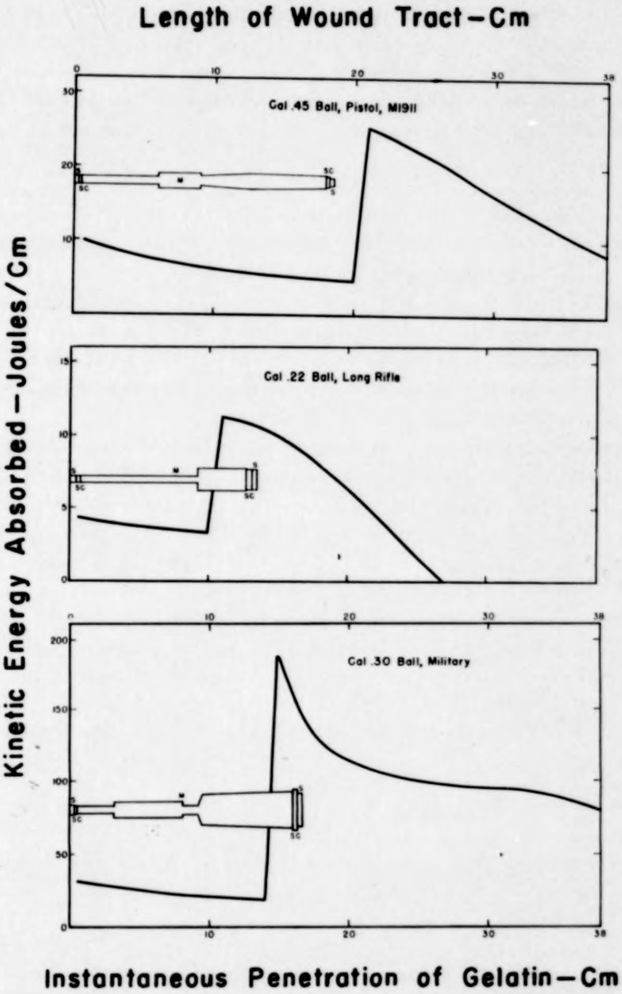


FIG. 3. Comparison of bullet wound tract dimensions and energy absorption from bullets by gelatin tissue models. M—Skeletal muscle; S—Skin; SC—Subcutaneous tissue.

RESULTS

In figures 2 and 3 schematic diagrams of the dimensions of the permanent wound tracts in the goat skeletal muscle are compared with the energy absorption from the same bullets fired into the 20% gelatin tissue models. The wound tracts diagrammed in these figures are from goats which were studied on the third or fourth day after wounding.

The differences among the five pistol bullets and the caliber .22 long rifle ball in their transmission of energy to the gelatin targets are small. Even when these bullets tumble, the increased amounts of energy absorbed by the targets do not amount to much. The high velocity caliber .30 military ball, however, transmits much more energy to the target than do the other bullets even when the military ball is stable. On tumbling, the energy transmission of this bullet increases markedly.

In the examples of pistol wounds shown in the charts only the wound tract produced by the caliber .32 revolver ball indicated possible effects of a tumbling bullet. At a penetration distance of 9.5 cm into the goat leg, the tract widened. In the gelatin target, tumbling by this bullet began at 9.0 cm into the gelatin.

Evidence of tumbling occurred in the wound tracts caused by both the caliber .22 long rifle ball and the caliber .30 military rifle ball. With the former, tumbling occurred at about the same distance of penetration in both the muscle and the gelatin; with the latter, tumbling took place in less distance of penetration into the muscle than into the gelatin tissue model.

Some approximate measurements can be made from the representative examples of wound tracts and energy relationships in gelatin tissue models shown in figures 2 and 3. The lengths and volumes of the permanent wound tracts can be determined from the autopsy data and the energy absorbed by equivalent lengths of gelatin tissue model can be measured (Table 2). The actual energies absorbed from the bullets by the goat muscles were not determined in these experiments although it is possible to do so.

The differences among the pistol bullets, other than the caliber .45 ball, are small. The effects of the caliber .45 ball are moderately greater than those of the other pistol bullets. The caliber .30 military rifle ball has markedly greater effects than does the caliber .45 ball on both the volume of the wound tract and

TABLE 2

Wound Tract and Gelatin Measurements

Bullet	Length of Wound Tract	Volume of Wound Tract	Volume of Wound Tract/cm	Striking Kinetic Energy of Bullet	Kinetic Energy Absorbed by Equivalent Length of Gelatin
	cm	*cc*	*cc*	*joules*	*joules*
Caliber .380 ball, pistol, automatic W380AP	11.8	2.8	0.2	222	80
Caliber .32 ball, pistol, automatic W32AP	16.5	3.2	0.2	159	80
Caliber .38 ball, revolver W38SWP	13.6	3.6	0.3	160	80
Caliber .32 ball, revolver W32SWP	18.3	6.3	0.3	96	90
Caliber .22 ball, long rifle	13.5	8.4	0.6	175	80
Caliber .45 ball, pistol, M1911	18.5	9.7	0.5	494	130
Caliber .30 ball, military	16.6	35.4	2.1	3579	730

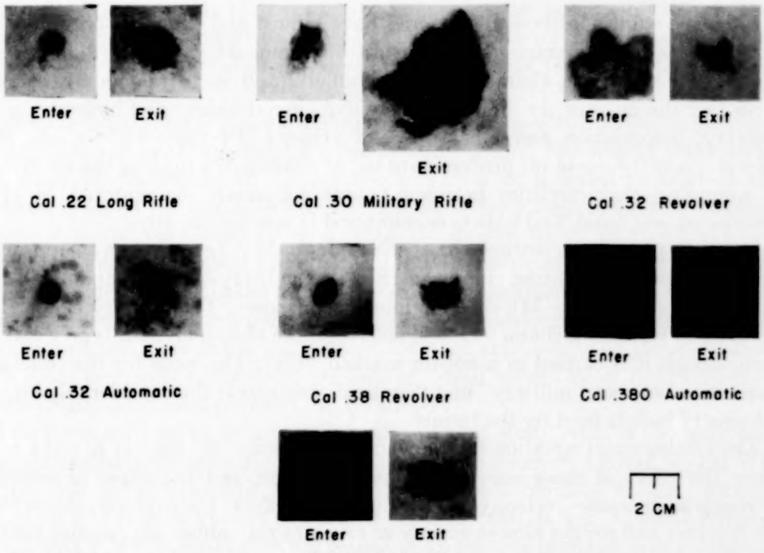
the amount of energy absorbed by equivalent lengths of gelatin tissue model. The caliber .22 long rifle ball appeared to produce somewhat more tissue damage than would be expected from its striking kinetic energy or gelatin energy absorption. However, the disproportion is not great.

Figure 4 illustrates representative entrance and exit wounds for all the seven bullets used. It is relatively easy to differentiate between the neat circular entrance wounds and the more ragged exit wounds. Only two of the exit wounds, those from the caliber .22 long rifle and caliber .30 military balls are noticeably larger than the corresponding entrance wounds. These two were apparently in tumbling motion as they perforated the skin on the exit side.

Forty-eight goats were used in this study. Of these 25 met the criteria of having wounds involving muscle in the major muscle mass of the thigh, avoiding fractures and major vessel damage. One other was studied separately because fracture of the left femur occurred. Eight of the 48 were omitted because of major vessel injury producing death from hemorrhage. The others were omitted because of unsatisfactory location of the wound.

The bullet passed entirely through both thighs except in one goat shot with the caliber .32 Smith and Wesson, and one with the caliber .38 Smith and Wesson. Only goats in which the bullet traversed both limbs were included in the study so that the muscle masses involved would be approximately equivalent.

In all wounds studied on the fourth post-wounding day immediately after injection of disulphine blue dye the stain extended to the edges of the permanent tract. This implies that all of the tissue except that lining the permanent tract


Enter
Exit
Col .22 Long Rifle
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Col .30 Military Rifle
Enter
Exit
Col .32 Revolver
Enter
Exit
Col .32 Automatic
Enter
Exit
Col .38 Revolver
Enter
Exit
Col .380 Automatic
Enter
Exit
Col .45 Automatic
2 CM

FIG. 4. Entrance and exit wounds three to four days after wounding by bullets

itself was viable. This dye has not been completely evaluated in this laboratory. However, when used in blast wounded animals, the wounds of which result in femoral artery damage (12), the tissue which does not stain immediately post wounding is black (necrotic) the following day.

In all of the wounds observed four days post wounding the only differences noted were that the permanent wound tract was larger in the wounds from the higher velocity missiles and in areas where bullets had tumbled. There was no gross zone of necrosis beyond the permanent wound tract in any of the animals examined and no gross evidence of infection, either aerobic or anaerobic.

The wounds in the animals left untreated for three to four weeks all healed spontaneously. The goat in which a comminuted fracture of the left femur occurred when shot with a caliber .32 automatic bullet was studied 36 days post injury. Complete pathological examination showed that the soft tissue had healed entirely without evidence of hematoma or infection, and the fracture was surrounded by callus without evidence of infection. No splinting, antibiotics, or other therapy had been used. The only notable difference between the caliber .30 rifle bullet tracts and the other is that the zone of scarring was slightly larger. However, this was very slight in all the wounds, being actually unidentifiable in several of the low velocity missile wounds. The microscopic studies are not included on this paper as they add practically nothing of clinical significance. No evidence was seen of extension of necrosis beyond the immediate vicinity of the permanent wound tract.

DISCUSSION

Intensive studies in these laboratories have refined and extended a number of earlier defined (14) parameters which are of significant weight in determining the relative wounding characteristics of bullets (and shell fragments). Among these are: the mass of the bullet, its shape, its aerodynamic and hydrodynamic stability, deformation and break-up, and velocity. Of these factors, the last named—velocity—is of far predominant importance in determining the difference in wounding characteristics between bullets commonly encountered in civil practice on one hand, and bullets encountered in war on the other.

In truth, there is no intrinsic or absolute distinction between the two groups. The high-powered hunting rifle is in effect a "military-type" weapon; indeed, one can buy a surplus M1 rifle for hunting purposes. The military caliber .45 pistol is, in wounding characteristics, nothing more than a civilian-type weapon, even though it is carried in a holster marked "US". The basis for the practical distinction between "military" and "civilian" weapons is the considerably higher velocity of bullets fired by the former.

The fundamental equation for the energy of a bullet in flight is $E = \frac{1}{2} mv^2$. Since the effect of mass increases in linear fashion, but the effect of velocity increases as its square, velocity has the far greater effect. For example, the caliber .38 revolver ball weighs almost exactly as much as the caliber .30 military bullet, but the velocity of the latter is 4 times as great; the net result is a 16-fold difference in energy. The caliber .45 pistol ball, M1911, weighs 50% more than the caliber .30 rifle ball, but with less than one third of the velocity of the latter, the pistol ball has only 1/7 as much energy. Even without consideration of factors such as stability and deformation, it is evident that the military rifle bullet has the potential of producing a wound much different from that produced by a police pistol or a "varmint" rifle.

In the teaching of military surgery, or indeed, surgery of trauma in general, it has been found necessary time and time again to emphasize that all devitalized tissue must be removed and that primary suture of a dirty wound containing necrotic tissue should never be done. This has been taught so vigorously that a surprising number of surgeons have gone to the other extreme, believing that all bullet wounds must be thoroughly debrided whether there is evidence of devitalized tissue or not. The fallacy lies partly in the definition of the term "debridement." As pointed out by Hampton (5), this unfortunate word means different things to different surgeons. A small perforating missile wound of the calf, for instance can perfectly well have lying beneath the fascia a large mass of severely damaged muscle. The resulting hematoma is not only an excellent culture medium, but with continued subfascial swelling can secondarily compress the uninjured vessels of the leg and so produce gangrene. Even a relatively low velocity bullet if it tumbles can produce this effect. In wartime when opportunity for continued close observation of the patient can not be assured, it is far more essential to incise the fascia so that the extent of deep injury can be evaluated and *treated*, and the closed fascial compartment decompressed. The higher velocity bullets impart much more energy and are more apt to produce tearing of very small blood vessels, and, by sheer chance direct vessel damage is more probable. The possibility of direct vessel damage is more because of the increased likelihood of fractures and therefore of bony fragments acting as secondary missiles (7). Naturally, obviously necrotic muscle and foreign material should be removed. However, once the area has been explored and no evidence of expanding hematoma or muscle destruction is seen, there is no reasonable justification for removing apparently normal tissue around the wound tract under the guise of "debridement." Surgical exploration of a missile wound of the buttock is sound because in this area it is possible for a large amount of bleeding to occur in the contaminated area, with the double threat of blood loss and secondary infection. Tissue necrosis from mere pressure of the liquefying hematoma can further predispose to anaerobic infection. Here, too, if there is no evidence of tissue destruction and hemostasis is adequate, it is hard to find justification for more extensive surgery for uncomplicated soft tissue wounds. The basic principles of avoiding pockets of "dead space" or of fluid collection in a contaminated area prevail as in all surgery.

It is most interesting to note that in the present study ALL of the untreated wounds healed spontaneously with no therapy whatsoever. During World War II the Yale group (cited by Harvey (6)) described complete healing, without treatment, in dogs wounded by steel spheres at 5000 ft/sec, whereas Ochsner (12) in our laboratory found in goats that thigh wounds inflicted with caliber .30 balls at comparable velocity were uniformly fatal. The lethal process was later demonstrated by Lindsey *et al.* (10) to be due to clostridial infection in the undebrided wound. The difference would appear to be due to circulatory damage: in the dogs the femoral artery was spared, in the goats it was compromised. It is the experience of our pathology laboratory that missile wounds of muscle in the goat with intact circulation do not show late necrosis. This is in contrast to wounds of the liver, in which a wider zone of necrosis histologically resembling an infarct develops around the wound tract within a few days after injury.

One wonders whether in clinical practice and teaching a sharper therapeutic distinction should be drawn between soft tissue wounds with definite circulatory impairment and those without it. Those in which there is obvious vascular damage have a far different prognosis from the standpoint of progressive tissue necrosis and development of anaerobic infection, as has been well shown by North (11) and others. It is not to be inferred that untreated wounds in man would necessarily heal as uneventfully as most "civilian-type" bullet wounds in goats do, although it is common experience that quite a few have. The goat wounds merely show the physical characteristics of the various types of wounds. It could be expected that the extent of immediate devitalization of tissues would be comparable, although the resistance or susceptibility to infection would not necessarily be the same in both species. It is of interest to note that larger wounds in the same region in these goats (wounds produced by an explosive charge) invariably, when untreated, develop a lethal infection with *Clostridium perfringens*, leading to death in about 25 to 30 hours of the unilaterally wounded animal. Positive cultures are obtained within 9 hours post-wounding (13). Therefore one can use this evidence to assume that the thigh muscles of the goat are not necessarily resistant to infection, with anaerobic organisms, at least. The large wounds mentioned differ from the bullet wounds in that there is usually damage to the femoral artery, the hemorrhage from which is controlled by hemostats. In the present study, no treatment whatsoever was given.

This study thus shows the far greater *physical* effect of the higher velocity bullet, but does not in itself show a correspondingly greater *pathological* effect.

CONCLUSIONS

1. Skeletal muscle wounds of the goat *in absence of obvious circulatory impairment* heal spontaneously even when produced by a high velocity military bullet.
2. It seems reasonable to conclude that, subject to clinical confirmation, the amount of debridement required for a bullet wound should depend more on the damage inflicted than on the nature of the missile.

ACKNOWLEDGMENT

The technical assistance of Mr. W. C. McDonald of the Wound Ballistics Branch, Biophysics Division is gratefully acknowledged. The Wound Assessment Branch, Dr. F. Light, Chief, performed the pathological examinations.

REFERENCES

1. BENNETT, J. E. AND LEWIS, E. Operative decompression of constricting burns. Surgery, **43**: 949–955, 1958.

2. Callender, G. E. and French, R. W. Wound ballistics; studies in the mechanism of wound production by rifle bullets. Mil. Surgeon, **77:** 177–201, 1935.
3. Crile, G. Jr. Experiences of the surgical service of the United States Naval Hospital, Auckland, New Zealand, with casualties from the initial Solomon Islands engagement. U. S. Nav. M. Bull., **41:** 306–324, March, 1943.
4. Ferguson, L. K. Observations on the treatment of battle wounds aboard a hospital ship. U. S. Nav. M. Bull., **41:** 299–305, March 1943.
5. Hampton, O. P., Jr. *Wounds of the Extremities in Military Surgery*, p. 72, C. V. Mosby Co., St. Louis, 1951.
6. Harvey, E. N. in *Advances in Military Medicine, I.* Little, Brown & Co., Boston, 1948.
7. Herget, C. M. in *Surgery of Trauma*, W. F. Bowers, ed. pp. 494–510, Lippincott, Philadelphia, 1953.
8. Hunter, J. *A Treatise on the Blood, Inflammation and Gun-shot Wounds*. London, 1794.
9. Inman, W. H. W. The use of Disulphine Blue in surgery. Imperial Chemical Industries, Ltd., Pharmaceuticals Division, Annual Techno-Commercial Conference, April, 1959.
10. Lindsey, D., Wise, H. M., Knecht, A. T., Noyes, H. E. and Sherman, R. The role of clostridia in mortality following an experimental wound in the goat. Surgery, **45:** 602–622, 1959.
11. North, J. P. Clostridial wound infections and gas gangrene; arterial damage as a modifying factor. Surgery, **21:** 364–372, 1947.
12. Ochsner, E. W. A., Jr., Jacob, S. W. and Mansberger, A. R., Jr. A new preparation for the study of experimental shock from massive wounds. I. Standardization. Surgery, **43:** 703–707, 1958.
13. Reid, W. T., Mendelson, J. A., Lowry, K. and Lindsey, D. Experimental gas gangrene: effect of clostridial and staphylococcal toxoide on survival time. Surgery, **48:** 796–804, 1960.
14. Wilson, L. B. in *The Medical Department of the United States Army in the World War*, XI, Part I, Chapt. 2, pp. 9–56, Washington, 1927.

DEBRIDEMENT OF CIVILIAN GUNSHOT WOUNDS OF SOFT TISSUE

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INTRODUCTION

The principle and practice of debridement of military wounds was one of the great advances of war-time surgery. It is important that debridement and other aspects of wound care conform to the type of injury so that morbidity and mortality be kept to a minimum. This paper demonstrates that the debridement of most civilian gunshot wounds involving soft tissue is unnecessary because most civilian firearms* are less destructive than military weapons.

For purposes of management, gunshot wounds may be classified in three groups. The first group, which requires no debridement, is caused by pistols and other civilian firearms with low destructive energy. The second group are the shotgun wounds. The destructive effects of these injuries and the need for debridement varies with the individual case. The third group are wounds caused by military or high-powered hunting rifles. These are rare in civilian life and are not discussed here. They should be debrided and managed according to military doctrine.

GROUP I—BULLET WOUNDS—NO DEBRIDEMENT

One hundred and five consecutive patients who sustained single gunshot wounds of soft tissue were treated at the Homer G. Phillips Hospital from January 1, 1956 to December 31, 1958. These wounds were caused by single bullets whose muzzle energy was less than 400 foot pounds and muzzle velocity less than 1200 feet per second.

It has been our policy not to debride or operate on such injuries. In order to evaluate the results of non-operative treatment, cases with potential sources of infection other than the missile, or cases that required operation for other reasons were excluded. Therefore, cases with bone, joint, nerve or vascular injuries, and cases of intra-abdominal, intra-thoracic or head and neck injuries are not discussed.

The hospital and out-patient records of these cases were reviewed in January, 1960, and further follow-up was obtained in all instances by either questionnaire, phone calls or information from friends and relatives.

Figure 1 shows that the age range of the patients resembles that of military

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* For the purposes of this paper "civilian firearms" are pistols and rifles whose bullets have a muzzle energy less than 400 foot pounds and these include police and military pistols.

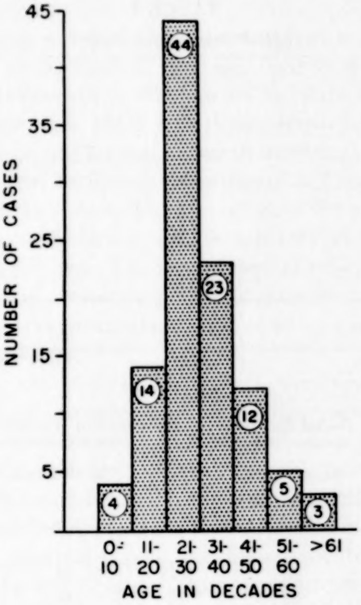

FIG. 1. Age distribution of 105 civilian cases of gunshot wounds

casualties, although 18 were older that 40 years and 15 patients were less than 20 years old. There were eleven women.

The distribution of the wounds is shown in Table I. Sixty wounds were through and through perforations and the bullet remained in the other 55 patients.

The weapons used are listed in Table II and it is noteworthy that the majority are .38 or .45 caliber pistols. These police or military pistols were the most powerful weapons encountered in this series and the muzzle energy of these bullets is less than 400 foot pounds less than 1200 feet per second. The muzzle energy of bullets from the military carbines or rifles is two to 30 times greater (1). Several shotgun wounds during the period of this study are discussed later.

Civilian shootings are almost always at close range. The circumstances of the shootings were not always described but in only four cases was the estimated distance more than 25 feet.

The majority of the patients were brought to the hospital within one hour of injury and in no case did the time exceed four hours. These civilian wounds were not sufficiently severe to cause clinical shock. Blood loss and swelling were not excessive and no blood transfusions were needed in any of these cases.

TREATMENT

All patients were hospitalized for examination and treatment. Treatment consisted of the following: the patient was put at rest; the surrounding skin was gently cleansed, and a dry sterile pressure dressing was applied. Wounded

TABLE I

Distribution of Injuries

Hand	4
Forearm	12
Brachium	24
Shoulder	6
Foot	2
Calf	14
Thigh	24
Trunk	7
Buttocks	14
Total cases	105

TABLE II

Bullet Ballistics in 105 Civilian Wounds

Weapon	Caliber	Bullet Weight	Muzzle Velocity	Muzzle Energy	Cases	Total
		grains	*feet/sec.*	*foot/pound*		
Pistols						72
	.22	40	1012	91	6	
	.25	50	733	60	4	
	.32	74	964	155	10	
	.38	130	1146	379	25	
	.45	200	910	368	3	
	Total				48	
	Unknown				24	
Rifles						9
	.22				6	
	Unknown				3	
Weapon unknown						24

Data are given for the most powerful cartridge and weapon in each caliber.

extremities were usually splinted and elevated. The wounds were not incised, probed or irrigated. The discolored edges of a wound of entrance were excised in four cases. The bullet was palpable in 15 cases and was removed through a small incision under local anesthesia prior to discharge.

Antibiotics were given to all but six cases. The most common was the penicillin-streptomycin combination parenterally or achromycin by mouth. The antibiotics were continued for five days in almost all cases.

Tetanus toxoid was given to patients who had been immunized less than five years prior to injury. All others received prophylactic tetanus antitoxin. Pentavalent gas gangrene antitoxin was given in eighteen cases.

RESULTS

The hospitalization and period of disability was short and no wound suppuration developed in these cases. Swelling, pain and fever were noted for a few days. The highest recorded temperatures are charted in figure 2. Seventeen patients had temperatures higher than 102°F but these elevations lasted less than 24 hours and the temperature was normal in two to three days.

Hospitalization was brief as illustrated in figure 3. Patients were discharged when ambulatory, when they were afebrile, and when the pain and swelling were subsiding. After discharge, antibiotics, usually achromycin, were given by mouth to complete the five day course. The mean hospital stay was two days. A few patients stayed longer than a week for diagnosis or treatment of delirium tremens (3 cases) or some coincidental medical disorder, or because of poor home facilities, or because they were prisoners.

After discharge from the hospital all patients were examined once or twice weekly in the clinic for one to three weeks until their wounds were healed. No infections developed. No readmissions, further antibiotics or surgical procedures for treatment of infection were necessary in these 105 patients.

Sixty patients were re-examined in the clinic three months to three years after injury. Forty patients who were unable to report for examination were questioned by telephone regarding disability, pain, etc. Four patients were out of contact but reliable information was obtained from close friends and relatives. Four patients complained of occasional stiffness or "aches" but there was no serious

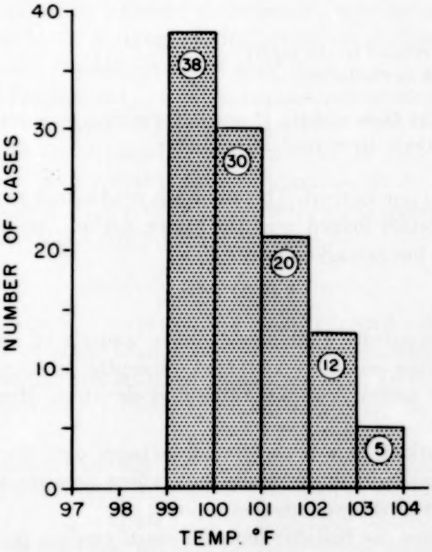

FIG. 2. Highest recorded temperature during convalescence from gunshot wounds—105 civilian cases

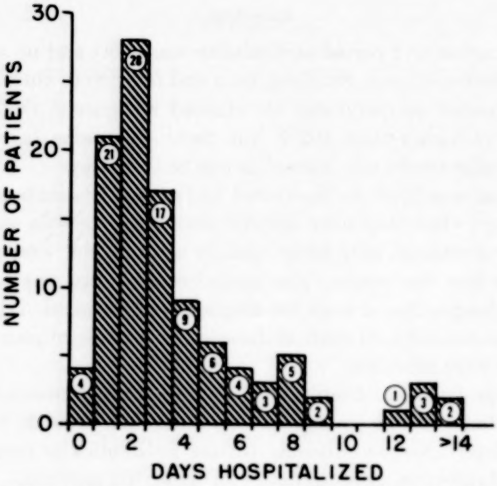

Fig. 3. Duration of hospitalization in 105 civilian gunshot wounds

TABLE III
105 Civilian Gunshot Wounds—Results of Non-Operative Treatment

Mortality	0
Morbidity	Minimal
Mean hospital stay	Two days
Infections	0
Subsequent surgery related to the injury	1*
Readmissions related to the injury	1*

* Removal of bullet from vicinity of sciatic nerve two years after initial injury. Follow-up is three months to three years after injury.

disability except in one patient. This man was readmitted two years after injury for removal of a bullet lodged near the sciatic nerve. The bullet remains in 39 other patients and has caused no symptoms.

DISCUSSION

These data demonstrate that single bullet wounds of soft tissue caused by the common civilian weapons will heal promptly with careful attention to wound care, strict asepsis, rest, splinting and elevation. However, debridement is unnecessary.

The civilian patient enjoys certain advantages over the military casualty because hospitalization is more rapid, the civilian firearms are less destructive, and contamination of the wounds less serious.

Table II indicates the ballistic data for usual civilian pistols and rifles. The wounding effect and tissue destruction correlates best with the energy transmitted and absorbed by the tissue (4). But many other factors influence the energy transmitted to the tissue, namely the velocity and directions of transmission and these in turn are related to the weight, velocity and stability of the bullet. In soft tissue or gelatin blocks experimental data regarding military weapons shows that the energy absorbed is proportional to the cavitation effect (4). When data are published regarding civilian weapons, we are confident that the experimental observations will demonstrate small energy absorption, slight cavitation and little tissue destruction from these civilian weapons (1). This conclusion is suggested by the clinical data in this paper and our clinical impressions from seven years experience.

Soft tissue destruction is worse when fragments of shattered bone become secondary missiles within the tissue. Therefore, Richards has reviewed cases of fracture due to civilian gunshot wounds in our hospital. No infection developed in 62 consecutive fractures due to civilian firearms treated without debridement (7). Vascular injuries require operation for the repair of the arteries or veins and evacuation of hematomas. We advocate radical debridement of all damaged artery and 1–2 cm. of normal artery so that invisible microscopic damage will will not cause delayed thrombosis (5).

GROUP II—SHOTGUN WOUNDS—DEBRIDEMENT

Shotgun wounds vary tremendously in the amount of destruction because of the variety of weapons, loads, distance, pattern of shot, etc. Surgical treatment of these civilian injuries requires careful evaluation of each case.

An occasional case will come for treatment several days after injury and if invasive infection is not established debridement may be safely accomplished with the help of antibiotic coverage. Shotgun wounds at close range may avulse skin and muscle over a wide area and may require skin grafting. Just as in military casualties the skin grafts are best applied four to six days after injury.

Shotgun wounds from light loads, such as birdshot fired at a distance seldom need debridement. However, swelling in the arm or leg may be troublesome. If swelling is moderate, hourly evaluation of the pulses, of the degree of swelling, and of the circulation detects arterial and arteriolar compression by progressive swelling. If in doubt, fasciotomy is mandatory.

SUMMARY AND CONCLUSIONS

1. One hundred and five consecutive civilian gunshot wounds of soft tissue are reported. None of these wounds was debrided. No infections or complications resulted. Disability and hospitalization were brief. Debridement is unnecessary for wounds caused by bullets whose muzzle energy is less than 400 foot pounds.
2. Civilian firearms are usually less destructive, hospitalization is more rapid and contamination of the wound is less serious than in military casualties.
3. Devitalized and contaminated tissue is equally hazardous to the civilian and soldier. This results from wounds by shotguns at close range or by high powered rifles. Such wounds require excision and treatment according to the principles tried and tested in military practice.

4. Shotgun wounds present a variety of problems. There may be tissue destruction and foreign bodies which require debridement. Massive swelling may occur within closed fascial spaces and fasciotomy may be necessary. Nerves and blood vessels are frequently injured by the multiple foreign bodies. Treatment of these wounds requires careful appraisal of the individual case.

REFERENCES

1. Dziemian, A. J., Mendelson, J. A. and Lindsey, D. Comparison of the wounding characteristics of some commonly encountered bullets. J. of Trauma, **1:** 341-353, 1961.
2. Gaffney, C. J. and Walker, W. B. Arterial homografts in the immediate treatment of severe injuries to a major artery. A.M.A. Arch. Surg., **74:** 555-556, 1957.
3. Hampton, O. P. *Wounds of the Extremity in Military Surgery*. C. V. Mosby Co., St. Louis, 1952.
4. Herget, C. M. Wound ballistics. *Surgery of Trauma*, W. F. Bowers, ed., J. B. Lippincott, Philadelphia, 1953.
5. Hershey, F. B. and Spencer, A. D. Surgical repair of civilian arterial injuries. A.M.A. Arch. Surg., **80:** 953-962, 1960.
6. Hoover, N. W. and Ivins, J. C. Wound debridement. A.M.A. Arch. Surg., **79:** 701-710, 1959.
7. Richards, W. and Holt, E. P., Jr. Treatment of civilian gunshot wounds of bones and joints. (To be published)

THE MANAGEMENT OF SOFT TISSUE MISSILE WOUNDS IN WAR AND PEACE

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We have known since the time of Ambroise Paré (1) that there is a "venonosity" of gunshot wounds not to be found in arrow or knife wounds and that the former are much more likely to become infected than the latter. In 1897, Friedrich (2) established the basis for debridement when he showed experimentally that infection could be prevented by the early excision of wounds contaminated with street dirt. The experimental work of Callender (3) and Dziemian (4) proved that tissue devitalization produced by a missile is directly proportional to the amount of energy transmitted by the missile to the tissue it traverses. Practical proof of each of these theses was discovered and rediscovered in each of our last three wars when it was found that only properly debrided wounds healed without infection.

A missile is a body in motion and as such has kinetic energy which may be calculated by the formula: $E = MV^2/2$

E = Kinetic energy
M = Mass
V = Velocity

From this formula we see that increase either in mass or velocity will increase a missile's energy. Harvey (5) demonstrated by microsecond x-ray exposures the effects of a missile traversing tissue and showed that a missile's energy is transmitted to the tissues along vector lines and produces a process known as "cavitation." The tissue is violently thrown away from the missile tract by the expended energy. The size of the area of cavitation is directly proportional to the energy transmitted. Tissue destruction in any given wound, however, is determined by biological characteristics as well as physical law. On this basis we know from actual experience that elastic tissues such as fascia and skin, and spongy tissues such as lung, show little devitalization when struck even by high velocity missiles. On the other hand, soft, bulky, homogeneous, solid tissues such as muscle bellies and liver and spleen are violently disorganized and devitalized by missile wounds. We can thus say that tissue destruction for any given wound will vary with the kinetic energy contained by the wounding agent; with the amount of this energy transmitted to the tissues (a function of the size, shape, velocity and aerodynamic stability of the missile); and with the density, structure, and blood supply of the tissue traversed. On this basis, low velocity, small caliber missiles striking only skin, fascia, tendon, or lung will produce only minimal devitalization. Large caliber, high velocity missiles traversing large muscle

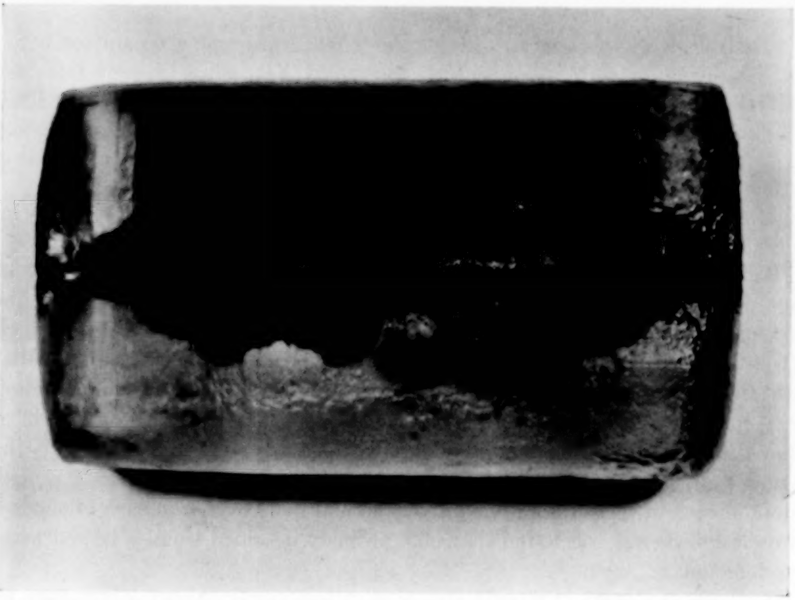

FIG. 1. Block of gelatin perforated by a caliber .30 missile which simultaneously perforated a packet of blue powder at one end and a packet of red powder at the other end of the block.

bellies and solid organs such as liver and spleen will produce maximal devitalization and will require extensive wound excision.

Every traumatic open wound is contaminated with microorganisms at the time of its production. The number and type of organisms present will vary with the conditions existent at time of wounding and the method of wound production. These organisms multiply, produce toxic products, overcome body defenses and produce systemic and local body reactions. The greater the amount of tissue devitalization, the more ideal is the pabulum for bacterial growth and the more difficult for the body to mobilize its local defenses to kill off these organisms. In missile wounds these organisms are carried into the depths of the tissue by the wounding agent or are sucked into the depths by the negative pressure wave of tissue cavitation. This is well illustrated in figure 1 in which a block of gelatin was perforated by a caliber .30 missile which simultaneously perforated a packet of blue powder at one end and a packet of red powder at the other end of the block. Note the mixture of red and blue dye within the block.

Contrary to public opinion, a wound of exit is not necessarily larger than a wound of entrance. The size of the skin wounds will vary with the stability of the missile, the shape and cohesiveness of the missile and with the clothing and bone carried into or out of the body. Contrary to popular opinion one cannot always tell by the skin wounds, the caliber of the missile which caused them. Nor can one tell by looking at the size of the wounds of entrance and exit the amount of tissue destruction which exists in the depths of a wound. To illustrate this point, compare figures 2 and 3. Both were produced by firing caliber .30 missiles into blocks of gelatin. In figure 2 the missile velocity was less than 1000 feet per second. In figure 3 the velocity was 2800 feet per second. In each figure the central light streak represents the missile tract and the elliptoid gray-black area represents the extent of cavitation and tissue devitalization. The volume of devitalization in figure 2 is less than that in figure 3, just as we would expect. Note, however, that the wounds of exit and entrance in each instance are the same size and from their size we could not predict the underlying amount of destruction.

On the basis of these physical effects of missiles on tissues certain principles of debridement were established during past wars and have been found to be effective in preventing morbidity and mortality. These principles include the following:

1. *Incision:* Because the aim of debridement is to excise all non-viable tissue, it is wise to plan an incision of sufficient length to permit exploration of the entire area of devitalization. It is impossible to accomplish adequate wound excision without adequate exposure, and this can be achieved only with an incision of sufficient length to permit visual inspection of the depths of the wound. Obviously, civilian type gunshot wounds can be exposed and explored through smaller incisions than can combat wounds because of the smaller extent of tissue devitalization anticipated. In wounds of extremities care must be taken to make the incision in the long axis of the extremity to facilitate closure. Wounds in flexion creases may be incised transversely. Some large round wounds or trans-

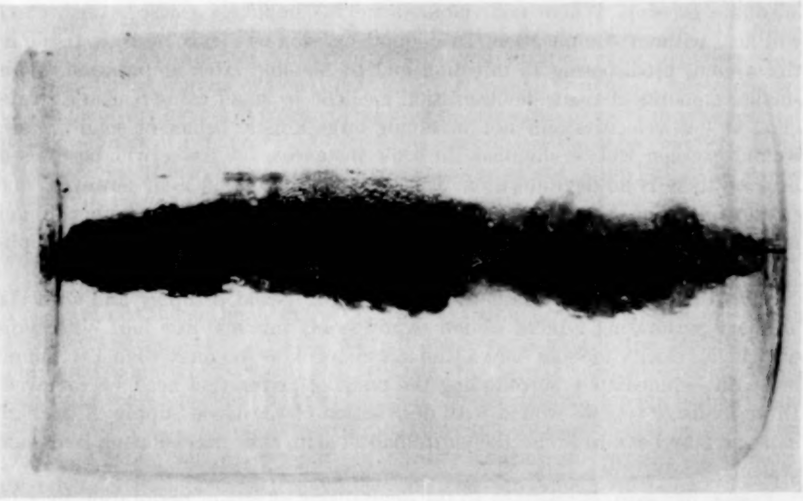

FIG. 2. Block of gelatin perforated by a caliber .30 missile at less than 1000 feet per second. (Arrow indicates missile tract)

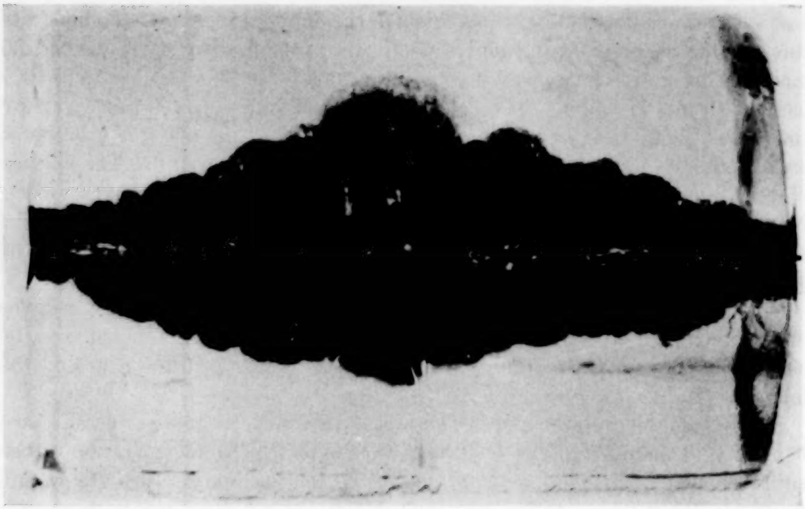

FIG. 3. Block of gelatin perforated by a caliber .30 missile at 2,800 feet per second (Arrow indicates missile tract)

verse wounds can be converted to incisions in the long axis of the extremity by utilizing "Z" type of incisions.

2. *Tissue Excision:* Results of treatment of wounds during past wars indicate that the incidence of infection and resultant morbidity depends entirely on adequate excision. Where non-viable tissue is completely excised, the wound will heal without complication. Inadequate excision will leave necrotic tissue in the wound, predisposing to infection and to possible later amputation. With smaller amounts of tissue devitalization incident to small caliber missiles traveling at low velocities and not involving large muscle bellies or solid organs, wound excision will be minimal. In some instances, no tissue will be excised because there is no devitalization. Unless the wound is incised, however, one cannot tell from the appearance of the entrance or exit wounds whether wound excision is required. To fail to do so when needed will result in wound complications and morbidity.

Skin is particularly resistant to destruction of its blood supply and with the ordinary perforating type of wound requires only minimal excision. With ordinary high velocity missiles only a thin margin of skin—no more than 1 to 2 mm. in width—immediately surrounding the point of perforation need be removed. In an avulsive type of wound with destruction of the blood supply of the skin flap one may have to excise the entire flap of skin, thus necessitating later skin grafting.

Fascia, like skin, is resistant to the devitalizing effects of perforation by missiles. Accordingly, fascial excision usually is limited to removing by sharp dissection only that which has been shredded or in which so much contaminating dirt and grime are imbedded that only excision can remove this debris. Obviously, loose-lying small fragments of fascia must be removed. Perforated fascia must, however, be incised to the full extent of the skin incision to permit exposure of the more extensively damaged underlying muscle.

Excision of muscle presents the most complex problem the tyro in the surgery of trauma must face. It is usually extensively damaged by missile wounds of the extremities and thus requires wide excision to accomplish adequate wound toilet. While the criteria on which muscle excision is based are definite, they require clinical judgment and therefore demand clinical experience.

a. Color: Devitalized muscle may vary from a dark hemorrhagic color to a pale fishbelly color, depending on the amount of hemorrhage into the local area and on whether the main blood supply to the muscle belly has been destroyed. Generally speaking, in an extremity in which the main vasculature has been lacerated so that external exsanguination may occur the muscle bellies will be pale. In the main, the intensity of color change depends directly on the time elapsed between wounding and the institution of surgical therapy.

b. Consistency: Normal muscle is relatively firm and rubbery. Devitalized muscle becomes soft and mushy, having lost its tone and elasticity.

c. Contractility: When normal muscle is pinched or cut it contracts sharply. In devitalized muscle, lack of contraction provides proof of non-viability. In any area of debridement, excision is continued until contractile muscle is encountered.

d. Normal muscle, when cut transversely, bleeds in amounts proportional to the size of the vessels cut in the course of the incision. In devitalized muscle, since the blood supply has been destroyed, fresh bleeding does not occur.

Debridement of all other tissues and organs is governed by the dictum that wounds containing only viable tissue will heal without infection. It is also governed by the difference in sensitivity to devitalization of various tissues and organs. Thus, wounds of bowel and lung rarely require extensive debridement. Wounds of the liver will fragment this organ or render parts of it avascular and mushy. These will have to be excised. Conservatism must be practiced in the excision of peripheral nervous tissue because the extent of devitalization cannot always be recognized clinically.

3. *General Wound Management:* While long and properly placed incisions coupled with adequate tissue excision will insure the removal of all devitalized tissue, other principles must be followed to assure successful healing. Typically these wounds should be irrigated with normal saline solution so that mechanical flushing will remove small particles and debris remaining in the depths. Where indicated, counterincisions in a dependent area permit adequate drainage from depths of a deep pocketing type of wound. Moderate-sized foreign bodies visualized by x-ray but not encountered during wound excision should be looked for, provided tissue barriers are not broken down during the search, for extensive search may lead to further devitalization and subsequent infection. Complete hemostasis should be accomplished so that the wound will remain dry and a medium for bacterial growth will not accumulate in the wound depths. The

type of suture material used for ligatures is not important. Dressings should be applied in such a way that drainage from the wound is not occluded. This requires the use of fine-mesh gauze laid on the wound, not packed into its depths.

4. *Wound Closure:* The process of wound healing in any wound is divided into two parts: (a) lytic phase, during which all devitalized tissue and contaminating organisms are lysed and carried away, and (b) proliferative phase during which actual repair and re-establishment of tissue continuity is accomplished. Any lag in (a) will necessarily delay the reparative phase of the process. The most common cause for delay is wound sepsis in which proliferation of contaminating organisms overwhelms local body defenses and cleansing of the wound cannot be accomplished. Overwhelming proliferation of contaminating organisms can occur only when local conditions are such as to promote it. This is true when (1) there is an overwhelming contamination with virulent resistant organisms, (2) hemostasis is inadequate so that a pabulum for bacterial growth is present, (3) devitalized tissue is not removed and organisms can grow in this medium, (4) lack of blood supply prevents local body defenses from becoming operative at the site. All of these conditions are correctible by wound excision and to fail to do so is a reprehensible surgical practice since it is so simple to do and results in such uniformly uncomplicated, well healed wounds.

In general, but with certain exceptions, missile wounds should not be closed primarily. Delayed closure permits later evaluation of the cleanliness of the wound, prevents locking in of infection, and does not delay wound healing. Proper management requires closure of these wounds four to ten days after debridement, provided there is no clinical evidence of infection. Because the so-called lytic phase of wound healing occupies a 72 to 96 hour period, clean wounds handled in this way contain only a minimal amount of granulation tissue, and after coaptation of the wound edges the productive phase of healing takes over to produce delayed primary healing. This method of closure does not delay wound healing and results in a wound which to all intents has healed per primam.

Wounds of the head, face, and neck may be closed primarily because of the excellent blood supply in these regions. In thoracic and abdominal wounds the pleura and peritoneum should be closed. In wounds of the brain and spinal cord the dura should be closed primarily. When nerves, tendons or large vessels are exposed in the depths of a wound they should be covered by adjacent tissues in order to prevent the drying out of these structures.

Rawles (6) demonstrated that soft-tissue wounds managed as outlined herein healed by first intention in 94.6 per cent of 391 wounds. Minimal reaction occurred in 3.8 per cent and gross infection in 1.5 per cent. It must be emphasized, however, that only adequately debrided wounds may be handled in this fashion. Frank purulent discharge from a wound, or redness, tenderness, and induration around its edges associated with abnormal elevation of the patient's temperature are indications of inadequacy of debridement. Such a wound should not be closed in four to ten days. Instead, a period of local soaks combined with secondary debridement may be required prior to secondary closure.

Authors of a recent publication on non-debridement of gunshot wounds produced by hand weapons advocate no surgical attack on these wounds. Instead, they use parenteral antibiotics and dressings. That this is an effective means of treating selected, small, low velocity missile wounds has been demonstrated in many wars. Even LeMaitre (7) in World War I wrote of this type of wound, "We believe it necessary to insist on the importance of complete clinical examination of the wounded before deciding to operate. Slight wounds and those which we know to be rarely infected can at once be eliminated from the list for operation. Such wounds are those with minute fragments in the face and hands which cause no injury to the bones and tendons, or to the joints. Wounds of this kind contain no fragments of cloth which are always loaded with bacteria and which are far more dangerous than the projectile itself." He very carefully alluded to the difficulty attendant upon deciding the amount of underlying tissue devitalization present on the basis of the size of the wounds of entrance and exit. The only way to decide whether wound excision should be accomplished and how much tissue to excise is by opening the wound tract and inspecting the involved tissues. No other method is completely satisfactory. All other methods inevitably must lead to a higher complication rate, higher morbidity, and increased mortality.

On this basis, I advocate that all missile wounds with the exception of the obviously intradermal ones or the "crease" type of wound be explored. If at the time of exploration no foreign bodies or tissue devitalization is found, the wound is sutured per primam. If tissue devitalization is found, this is excised and the clean open wound is covered with a sterile dressing. If there is no clinical evidence of infection during the postoperative period this dressing is not changed until the patient is taken to the operating room on the fourth to sixth post-debridement day. If at this time the wound is clinically clean, wire sutures are used for coaptation of skin and fascia. This method of management has led to uniformly excellent results for me in gunshot wounds, both in combat and in peacetime.

REFERENCES

1. Keynes, G. *The Apologie and Treatise of Ambroise Paré.* Chicago, University of Chicago Press, 1952.
2. Friedrich, P. L. Die aseptische Versorgung frischer Wunden. Arch. klin. Chir. **57:** 288, 1897.
3. Callender, G. R. and French, R. W. Wound ballistics. Studies in the mechanism of wound production by rifle bullets. Mil. Surgeon **77:** 177, 1935.
4. Dziemian, A. J. Wound Ballistics of the .30 Caliber M2 Rifle Ball. Chemical Corps Medical Laboratories Research Report No. 106 (March 1952).
5. Harvey, E. N. *Advances in Military Medicine,* Vol. 1, Chapter XVIII, Boston, Little Brown, and Co., 1948.
6. Rawles, B. W. Repair of soft tissue war injuries. Ann. Surg. **123:** 209 (February), 1946.
7. LeMaitre, R. Suture of war wounds. War Medicine **2:** 790, 1918–1919.

THE INDICATIONS FOR DEBRIDEMENT OF GUN SHOT (BULLET) WOUNDS OF THE EXTREMITIES IN CIVILIAN PRACTICE

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In recent years an old controversy concerning the surgical management of bullet wounds of the extremities in civilian surgery has been revived. Experiences in World War II and the Korean War clearly demonstrated the clinical indication for classical initial wound surgery (debridement) for bullet wounds in military surgery if the dire consequences of deep wound sepsis and perhaps gas gangrene were to be minimized. Naturally surgeons experienced in the early management of the war wounded extended the same concepts into their surgical management of civilian casualties with bullet wounds in the post-war period and generally have practiced debridement of bullet wounds in civilian surgery even though practically all could recall an occasional instance in their military experience when penetrating or perforating bullet wounds remained undebrided for varying reasons and yet healed promptly without sepsis.

Meanwhile many surgeons including some post-war graduates and trainees without military experience had often omitted debridement in their management of bullet wounds of the extremities except on special indications with satisfactory results. As a rule, wounds of entry and exit were cleansed and dressed, antibiotics were given and the extremities were kept at relative rest for a few days. The great majority of these wounds are said to have healed promptly without sepsis.

These conflicting surgical approaches for these wounds have caused many dressing and cloak room debates and have been subjects of heated staff meetings in many hospitals. Even today the question is always good for an argument. This situation probably prompted the Program Committee to select this subject for presentation on this Symposium on Trauma.

The wounding capacity of a bullet depends upon several variables. These include its mass, shape and tumble within the tissues but above all its velocity as it strikes and passes through the tissues. Velocity is so important that it alone may serve as an indicator of expected damage to the tissues. Wounds vary in direct proportion to the mass of several bullets but with the square of their velocity or according to some authorities to the cube of their velocity.

Bullets fired from military weapons for practical purposes are all high velocity missiles. Garand or M-1 rifle and 30 m.m. machine gun bullets travel at about 2800 feet per second. Other military bullets reach a velocity of 5000 to 10,000 feet per second. A high velocity bullet (over 2000 feet per second) imparts a tremendous amount of energy to the tissues creating an explosive effect within

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them. The result is a broad irregular cavitation accompanied by a widespread tearing disruptive action. Tissues some distance from the track of the missile may be damaged. Arterial supply to muscles remote from the bullet track may be destroyed. Bones may be broken without impact of the bullet. A bullet passing through the abdomen may produce pulmonary and even cardiac damage.

By contrast bullets fired from civilian weapons are usually of low velocity (less than 1000 feet per second). The 45 pistol bullet travels at 846 feet per second, 32 and 38 revolver bullets at about 600 feet per second and a 22 long rifle bullet at only 1206 feet per second. The energy imparted to the tissues is correspondingly much less. While some cavitation takes place it is minimal compared to that produced by truly high velocity missiles and therefore tissue damage is much less. Relatively little bleeding into the tissues is likely to follow. Of course, if a large vessel is torn a massive hematoma may develop.

The variations of wounding effects of bullets of varying velocity, mass and tumble have been demonstrated repeatedly. Excellent treatises have been published by Wilson, Callander and E. Newton Harvey. Recently Dziemian, Mendelson and Lindsey at the Army Chemical Center have made a number of observations on the action of both slow and high velocity missiles. They extended previous research to include detailed gross and at times microscopic studies of the wound tracks and the surrounding area obviously included in the cavitation produced as the bullet traversed the extremity. They appear to have demonstrated that a low velocity missile produces permanent damage only in the area bordering the track and, of great interest, despite the tremendous cavitation produced by a high velocity missile, permanent damage again was only that immediately surrounding the track of the missile provided the entire blood supply to a muscle or the major vascular supply was not destroyed.

Harvey reporting on observations in dogs by the Yale University group and Lindsey and his co-workers reporting on their work using goats both stated that slow velocity bullet wounds of the extremities without damage to major arteries had healed without debridement of the wounds. Theoretically, these investigators should have found that high velocity bullet wounds in comparable animals treated without debridement had all developed raging sepsis. Not so! Harvey reported spontaneous healing of untreated wide-open wounds with much loss of tissue in the thighs of dogs after wounding with a 7/32 inch steel sphere with a velocity of 5000 feet per second. He observed significantly that the wide-open wound provided excellent drainage from the beginning and the animal was permitted freedom of movement during the course of healing with early active motion of the extremity. The animal licked the surface aspects of the wound but not the deeper portion. The wounds were free of foreign material. The Lindsey group, I believe to their amazement, found that huge wounds in the thighs of goats produced by a .30 military ball traveling 2844 feet per second also healed without wound surgery or antibiotics. The skin of the area of wounding had not been prepared surgically although the hair was shaved.

All of these observations were in animals. Some of us still feel that there is some merit to the profound observation, made previously by Gimble I am told, that animal research may be principally of benefit to the Veterinarian. Will the implications of these observations particularly on slow velocity bullets hold up in humans? Some data are available.

Morgan, Spencer and Hershey at the 1960 meeting of the American Association for the Surgery of Trauma reported that 105 consecutive bullet wounds of the soft parts of the extremities at the Homer G. Phillips Hospital in St. Louis had healed promptly without wound debridement. Merely wound cleansing and dressing was employed although all received antibiotics. Richards and Holt (unpublished) at the same institution studied 60 bullet wounds of the extremities which produced fractures. In 57 the wounds were merely cleansed and dressed and covered by the cast used to immobilize the fracture. Some debridement was carried out on one wound of a hand and arthrotomy of the knee was performed in two patients who had bullet wounds penetrating the joint. Antibiotics were given to all. Prompt wound healing was obtained in 55 wounds which were not debrided and in the three which were. Low grade sepsis was observed in one undebrided wound which traversed the inner side of the lower portion of the leg and actually split off the medial malleolus. The other undebrided bullet wound involved the buttock and pelvis and had been produced by a relatively high velocity bullet from a deer hunting rifle. Rather fulminating sepsis followed in this instance requiring considerable delayed surgery.

Mahoney in his discussion of the paper by Morgan et al reported 37 consecutive bullet wounds of the extremities from Bellevue Hospital, some with and some without fractures, all managed without debridement of the wounds with most satisfactory results. Harrison, in additional discussion, stated that in Houston, Texas, 54 open fractures of the femur resulting from bullet wounds had been managed without wound debridement. All had gone on to wound healing without wound suppuration. Delayed intramedullary nailing was carried out successfully in about 40 per cent.

Other data were obtained from several medical centers in response to questionnaire. This information is gratefully acknowledged.

At Ohio State University Hospital, Roger Williams found that of 43 bullet wounds of the extremities including 11 with fractures, 10 had the wounds merely cleansed and dressed and 23 had minor debridement. Of these 33, prompt healing occurred in 31 and 2 had minor sepsis presumably of no significance. Ten had classical debridement. Apparently these also did well but minor sepsis occurred in at least one.

From The John Sealy Hospital at Galveston, Texas, Eggers and Sarris reported on 23 bullet wounds of the soft parts of the extremities. Eleven had no real debridement and 12 had classical debridement. Of these, 20 healed promptly and one was lost to follow-up. Apparently two came to amputation because of severe vascular damage. I conclude that both were in the group which had debridement originally. Of 46 bullet wounds with fractures, only 23 had classical debridement. Three came to amputation because of severe vascular damage, three had low grade sepsis with early wound healing, 37 healed promptly and 3 were lost.

Robert Freeark states that the regimen in vogue at Cook County Hospital is to merely cleanse the wound, irrigate superficially and apply a dressing unless vascular damage is present or bone is exposed in the wound. Detailed results are not available now but in the last 86 bullet wounds of the extremities, nothing has occurred to lead to a change in this policy.

Roger Sherman at the University of Tennessee in Memphis reported that the experience there indicates that through and through bullet wounds of the soft parts managed with minor debridement, irrigation and a sterile dressing sometimes with a small incision have all done well. He states further that in patients with wounds of entrance only, exploration is rather strongly indicated because they have found such wounds frequently contain bits of clothing, leather jackets, buttons and the like within their depths. He added the following significant statement. "The question which you are to discuss in March is a most important one, especially when one considers the possibility of nuclear explosions among the civil population. Indications from studies on experimental wounds in animals are that missile injuries in survivors resulting from such a blast will be 'low velocity' wounds and the question of the degree of surgical procedure necessary for their management may be tremendously important in terms of available surgical help and material."

These data show that, of 368 bullet wounds of the extremities about half with fractures, more than 300 were managed without wound debridement without loss of life or limb due to sepsis. The only patient with fulminating sepsis had sustained a relatively high velocity bullet wound which included an open fracture of the wing of the ilium. Gas gangrene was not reported. Almost all healed promptly without incident.

These experiences indicate that neither a classical surgical debridement nor a debridement by any definition is necessary for the great majority of bullet wounds of the extremities seen in civilian practice. Even so, each wound should be considered on its own merits. Wounds produced by the same size bullets from the same gun at the same distance will not all be alike. They will vary with the site of the wound, the tissues struck and damaged and the amount of bleeding within them. Good clinical judgement often must supercede any policy of no debridement of these wounds.

Debridement of any wound is designed to relieve the area of excessive tension, rid it of dead tissue and massive hematoma and provide excellent drainage. Perhaps relief of tension is the most important contribution of wound debridement. When the tissues of the part penetrated or perforated by a bullet are badly swollen within a tight fascial sleeve, certainly the first step of debridement, a free incision of adequate length through skin and fascia, must be done. Such an appearance to the part negates a watchful waiting policy. Following free incision and evacuation of the hematoma, gentle retraction affords an appraisal of the viability of muscle. Obviously dead and devitalized tissue should be removed but apparently low velocity bullet wounds produce very little death of muscle tissue. The studies of Lindsey and his group demonstrated repeatedly that the amount of dead tissue surrounding the bullet tract was actually only a few cells deep, microscopic rather than macroscopic. Thorough irrigation completes the debridement of the wound. If this amount of surgery has been indicated, then certainly immediate closure of the wound usually is contraindicated and it should be left open and dressed so as to provide splendid drainage. Such a wound should be clinically clean at the first dressing four or five days later at which time delayed closure usually will be advisable.

Clinical signs of injury to a major artery certainly dictate a classical debridement of the wound so that appropriate arterial surgery may be carried out promptly. Such a wound, however, is likely to be associated with massive hematoma formation with the area badly swollen so that the indication for some surgery on the wound is quite apparent.

The presence of a fracture in itself is no indication for wound debridement. Massive hematoma formation may dictate this surgery, but as a rule, the fragments of bone should go undisturbed. A totally loose chip easily accessible may be removed and any badly rotated large fragments may be nudged toward reduction. Very rarely, internal fixation may be indicated but the burden of proof is on the surgeon who uses it.

The summary of this presentation is merely that the great majority of bullet wounds of the extremities with or without fracture seen in the practice of civilian surgery apparently require no real surgery on the wound. This concept however, must be discarded in favor of an adequate and at times aggressive surgical approach when the characteristics of the wound so dictate.

REFERENCES

1. Callender, G. R. Wound Ballistics. Mechanism of production of wounds by small arms bullets and shell fragments, War Medicine, **3:** 337–350, April, 1943.
2. Dziemian, A. M., Mendelson, J. and Lindsey, D. Comparison of the wounding characteristics of some commonly encountered bullets. J. of Trauma, **1:** 341–353, 1961.
3. Hampton, O. P., Jr. *Wounds of the Extremities in Military Surgery.* C. V. Mosby Co., St. Louis, 1951.
4. Harvey, E. N. Studies on Wound Ballistics in Service in World War II. *Advances in Military Medicine,* Vol. 1, Brown, Little & Co., Boston, 1948.
5. Herget, C. M. Wound ballistics. *Surgery of Trauma.* W. F. Bowers, ed. J. B. Lippincott, Philadelphia, 1953.
6. Morgan, M. M., Spencer, A. D. and Hershey, F. B. Debridement of civilian gunshot wounds of soft tissue. J. of Trauma, July; 1961.
7. Richards, W. and Holt, E. P., Jr. Treatment of gunshot wounds involving bones and joint in civilian surgery (unpublished).

FRACTURES OF THE HIP IN PATIENTS WITH SEVERE OSTEOPOROSIS

The Effect of Collapatite Pegs on the Process of Healing*

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This report consists of two parts: the first deals with the incidence of severe senile osteoporosis of the spine in patients with fractures of the hip; the second presents a progress report of observations on the use of Collapatite as a substitute for metal for internal fixation of fractures of the neck of the femur in patients with severe osteoporosis.

The large number of unsatisfactory results in fractures of the hip have been attributed to many factors: (1) failure to reduce and impact the fracture, (2) faulty or repeated insertions of a nail, (3) injury to the blood supply to the femoral head, and (4) inadequate internal fixation and detrimental motion at the fracture site. The latter, as will be presented in this report, is often due to insufficient bone substance to hold metal inside an osteoporotic neck of the femur. Combinations of the four factors undoubtedly account for failure of the fracture to unite in many cases. Nevertheless, the importance of osteoporosis and its early recognition as one factor influencing incidence, choice of treatment, complications, and nonunion of femoral neck fractures deserves special emphasis. Osteoporotic bones were often intolerant of metal and many of our patients might have been managed better by closed methods without internal fixation, nails, nail-plates, or prostheses.

MATERIALS AND METHODS

Twenty-four patients admitted to four hospitals for fractures of the hip, during the period from 1948 to 1953, were found to have had previous x-ray examinations of the spine and treatment for severe osteoporosis. Special x-ray examination of 100 consecutive women with hip fractures revealed seventy-six additional cases of osteoporosis during the period from 1953 to 1959 (19). A statistical analysis of the classification, complications, and end-results of these patients have been reported in a previous communication (19). For the present

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study, bone pegs were made of a derivative of bone named Collapatite; this material consists of collagen and bone mineral after extraction of a large part of the intracellular and extracellular protein. An analysis of the breaking strength of Collapatite, compared with other materials, is shown in Table I. The results of the use of Collapatite in ten cases two years after open reduction with internal fixation is shown in Table II. A second group of ten cases examined one year after the operation is reported in Table III.

At the time of either a nailing or peg operation, specimens were obtained for study from the lateral cortex of the femur, 3.0 cm. distal to the externus tubercle of the greater trochanter; whenever the fracture was comminuted, a small fragment of the neck of the femur also became available for microscopic examina-

TABLE I

Tinus-Olsen Tests of Breaking Strength of Cortical Strips

Treatment	Lbs/2" Span†	
	Human	Bovine
Autopsy, fresh	970	1960
Lyophilized	158	980
Autoclaved	660	1320
Collapatite, autoclaved	176	290
Collapatite, lyophilized	289	480
Trifin nail*	500 (bending)	
Bifin nail*	800 (bending)	
"Z-nail"*	180 (bending)	

* Stainless steel.
† Average of 3 tests.

TABLE II

Fractures of the Neck of the Femur Treated by Internal Fixation with an Autoclaved Collapatite Peg (Two to Three-Year Results)

Case No.	Age	Classification of Fracture	Source†	Months to Produce Union*
1	82	Basal neck	B	8
2	74	Subcapital	B	9
3	94	Subcapital	B	M‡
4	91	Subcapital	B	H‡
5	68	Basal neck	B	6
6	70	Subcapital	B	11
7	74	Subcapital	H	9
8	76	Subcapital	H	9
9	80	Subcapital	H	C‡
10	64	Subcapital	B	12

* = Union and full-weight bearing.
†B = Bovine; H = Human.
‡ = Deceased; M, myocardial failure; H, cerebral hemorrhage; C, carcinomatosis.

TABLE III

Fractures of Neck of Femur Treated by β-Propriolactone Sterilized Collapatite Peg (One-Year Results)

Case No.	Age	Classification	Months to Produce Union*
11	72	Subcapital	10
12	65	Subcapital	10
13	56	Mid-cervical	M†
14	67	Mid-cervical	6
15	76	Subcapital	12
16	90	Subcapital	M†
17	69	Subcapital	Su
18	65	Basal neck	6
19	90	Subcapital	8
20	80	Subcapital	6

* Union and full-weight bearing.
† = Deceased; M†, myocardial failure.
Su = Superficial wound infection, delayed union, possibly avascular necrosis.

tion and comparison with bone from the neck of the femur of non-osteoporotic patients. The specimens were sectioned undecalcified on a bone mill, 100 μ in thickness and examined by microradiographic and histologic methods.

Radiologic and Histophysiologic Features of Osteoporosis: The diagnosis of osteoporosis in the cases presented in this report was based upon deformation rather than merely reduced density of bone. The roentgenograms showed three or all of the following signs: (1) collapsed vertebra in the dorsal spine, (2) expanded intervertebral discs in the lumbar spine, (3) a thin cortex in bone of the above areas of the spine, (4) accentuation of the vertical trabecular markings in the interior of the vertebral bodies and the head of the femur due to preferential absorption of the horizontal trabeculae (Fig. 1).

The microradiographic structure of the cortex in patients with osteoporosis showed an extreme degree of the bone changes normally associated with aging. A characteristic distribution of these changes, however, was found in osteoporotics with fractured hips. The thickness of the cortex of the lateral aspect of the femur, 3.0 cm. distal to the externus tubercle was only 30 per cent of the thickness of the cortex in non-osteoporotic individuals. On the endosteal surface of the cortex, the vascular channels were greatly enlarged. The low density lamellae in osteoporotics were equally as prominent as in normal bone; it is not yet clear whether this represents new bone or old bone not calcified to its fullest capacity. Haversian canals, plugged up with calcium deposits, were more numerous in osteoporotic bones than normal bone; this could be a manifestation of arteriosclerosis.

There was a remarkable absence of osteoblasts and no evidence of osteoclasts in histological sections of cortical bone. In general, the overall microscopic picture suggested that osteoporosis may be considered a disturbance of the process of remodelling, or replacement, of new Haversian systems. The humoral

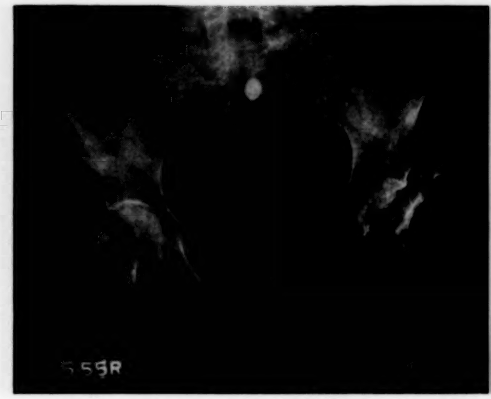

FIG. 1-A

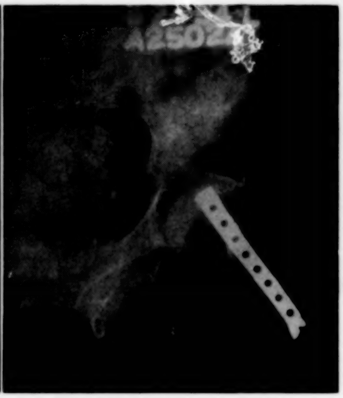

FIG. 1-B

FIG. 1-A. Roentgenogram showing a fracture of the right hip, six months postoperative, with absorption of the femoral neck, and nonunion in a seventy-four-year-old woman with senile osteoporosis.

FIG. 1-B. Roentgenogram of the same patient as shown in Fig. 1-A, following removal of the "Z-nail." Note the channel, 3 to 5 cm. wide, through the greater trochanter, caused by absorption of osteoporotic bone around the "Z-nail."

factors controlling this process are not known, and the cause of either postmenopausal or senile osteoporosis is still quite obscure. Various laboratory studies were performed on many of the patients described in this report, and have been presented in previous communications (17, 18).

I. HIP FRACTURES IN OSTEOPOROTIC PATIENTS

Fractures occurred in the proximal end of the femur at various levels in patients with osteoporosis. There was usually only a trivial injury or no injury at all. There was no apparent site of predilection for the fracture. In the majority of cases, the fractures were more comminuted than generally seen in non-osteoporotic individuals. The intertrochanteric region was often highly rarified, fragmented, and very brittle. The femoral neck consisted of a paper-thin shell of bone. The subcapital fractures were almost invariably spiral fractures with splintering of the posterior cortex. When patients with osteoporosis were treated with the same appliances as non-osteoporotics, for example, with metallic internal fixation (or a prosthesis) of seven different designs, approximately half of the patients had poor results (19). The splintering of the posterior aspect of the femoral neck in osteoporotic hips caused the fracture to angulate and made reduction difficult to hold; these were the so-called unstable adduction fractures.

Complications: Two months after a metallic nail was used to transfix the femoral neck, the splintered cortical bone was absorbed, and the metal was extruded backward in twelve instances. When a nail-plate was used for internal

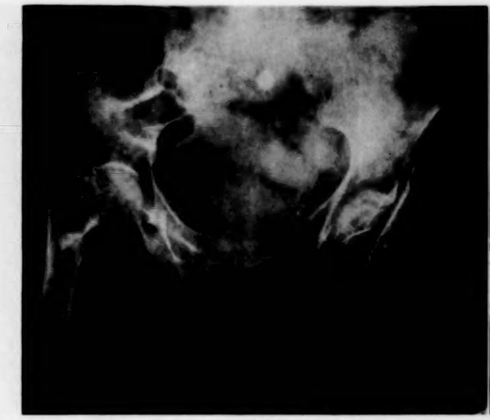

FIG. 1-C

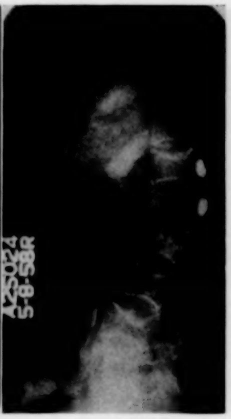

FIG. 1-D

FIG. 1-C. Roentgenogram showing a comminuted intertrochanteric fracture of the left hip, incurred by merely lifting the patient (same case as shown in Figs. 1-A and 1-B) out of the bed and into a wheelchair. A lateral view of the spine in this case is shown in Fig. 1-D.

FIG. 1-D. Roentgenogram of the spine in the lateral view, of the patient shown in Figs. 1-A to 1-C, shows expanded discs of the third lumbar intervertebra, a collapsed second lumbar vertebral body, everywhere a thin cortex, and calcification of the aorta. The pantopaque in the spinal canal had been injected eight years previously when the patient complained of low back pain and sciatica and was erroneously believed to have had intervertebral disc disease. The subsequent course of events and the collapse of the vertebral body revealed the diagnosis of postmenopausal or senile osteoporosis.

fixation of intertrochanteric fractures, the dissolution of the splintered cortex resulted in migration of the end of the nail into the joint. The metal appliances broke before union could occur in four patients. The design of the nail appeared to have no bearing on its efficiency in transfixing osteoporotic-brittle bone. In four cases in which a prosthesis was used, the metallic femoral head either drifted through the thin articular cortex of the acetabulum or became so loose around the stem that there was painful piston action of the prosthesis inside the marrow cavity of the femur (Fig. 2).

End-Results: The end-results in forty-nine osteoporotic intracapsular fractures were of special interest because the percentage of failures was higher than in unselected cases generally reported in the literature. In a group of thirty of our patients who survived for two years, fourteen had nonunion and two were treated with a prosthesis per primam (19). Thus, it appears that the chances of restoration of function of the hip joint is only 50 per cent in osteoporotics compared with approximately 70 per cent reported in the literature on unselected or non-osteoporotic patients.

An even more impressive view of the association of osteoporosis with the poor results of fracture of the hip are the findings in a spine survey in twenty-five consecutive cases of nonunion in subcapital fractures treated by eleven

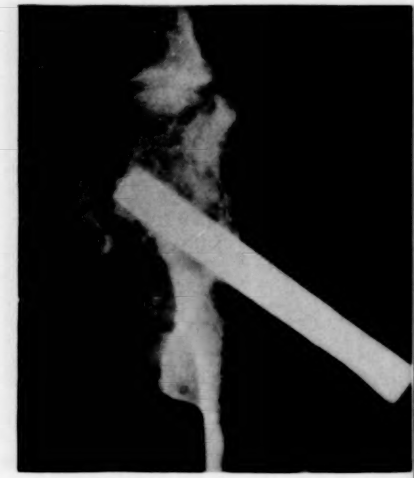

FIG. 2-A

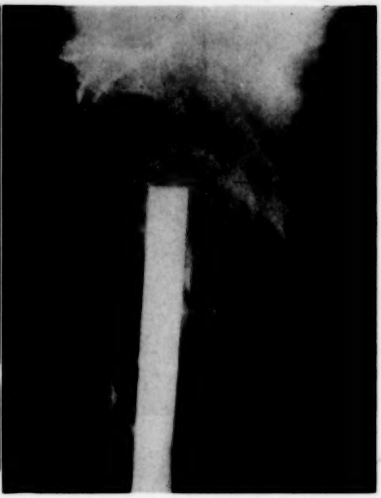

FIG. 2-B

FIG. 2-A. Roentgenogram of a subcapital fracture in a seventy-four-year-old man, three months after the injury, showing "nail slippage" and displacement of "brittle fragments" of the osteoporotic femoral neck.

FIG. 2-B. Roentgenogram in the lateral view in the same case as shown in Fig. 2-A. Note the splintering and displacement of the fragments of the posterior aspect of the neck of the femur.

different surgeons in two large hospitals (19). Approximately 84 per cent had collapsed vertebra and severe osteoporosis of the spine preceding and associated with the fracture of the hip.

These results showed very clearly that it is unwise to treat fractured hips by one method (nailing) to the exclusion of others. It also became clear that it might be wiser, in selected cases, to employ closed treatment, or nonmetallic material for internal fixation, assuming that Collapatite might be better tolerated and less apt to cause nail slippage and other complications.

II. FEMORAL NECK FRACTURES TREATED WITH A COLLAPATITE PEG

Preparation of Collapatite Peg: Collapatite consists of a derivative of human or calf bone, excised sterile at autopsies at U. S. Naval Hospital, Bethesda, Maryland, Tissue Bank, or at the Animal Processing Plant of Squibb Institute for Medical Research. The sterile cortical bone was cut in strips, 10.0 to 12.0 cm. in length, 2.0 to 2.5 cm. in width, and full thickness of the cortex (usually 7 to 8 mm.) with the aid of an electric motor saw. These pegs were thus at least 9 mm. wider than the standard trifin (1.1 mm.) nail in order to fill the hollow neck of the femur of the osteoporotic hip. (The average adult human female fibula measured approximately 13 mm. in diameter and was too small for good fixation of an osteoporotic femoral neck. The standard hip nails and nail-plates were also too small in diameter to fill the femoral neck of a patient with osteoporosis.)

Collapatite was prepared from strips of cortical bone by extraction of the intracellular and extracellular protein, to the exclusion of the collagen and bone mineral as far as possible. For use in Cases Nos. 1 to 10, the extraction procedure consisted of successive treatment in 8 per cent urea, dilute solution of chymotrypsin, 8.8 per cent saline, petroleum ether, autoclaving, and drying. The purpose of the urea was to increase permeability of the cell membranes of the osteocytes and other cells; chymotrypsin was to digest noncollagenous protein; 8.8 per cent saline was to solubilize protein; ether was to remove fat; drying was to restore hardness. After tests were made of the breaking strength of the cortical strips, the procedure was modified and the autoclaving was omitted. Autoclaving converted the collagen to gelatin and produced serious loss of mechanical strength. Lyophilization was less harmful in this respect but removed too much water and this also weakened the structure of the cortical strips. By using heavier bovine strips, measuring 1.0 cm. or more in thickness, it is possible to compensate to a considerable extent for weakness produced by autoclaving or lyophilizing, but this was trustworthy only when used in well-impacted fractures or when good contact-compression of the fragments had been obtained by telescoping the neck into the head at open operation.

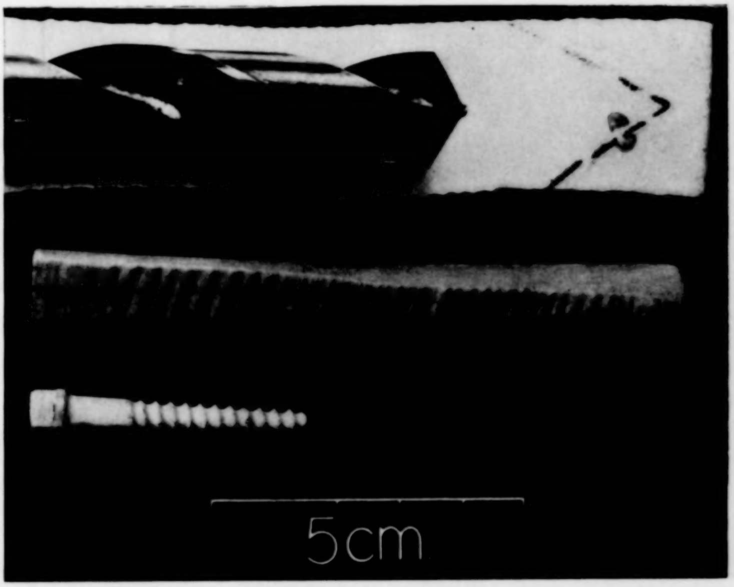

FIG. 3. Photograph showing 1.5 cm. drill point and 2.0 cm. strip of bovine Collapatite (top); another strip turned on its side to show the thickness (center), and a screw that was machined from Collapatite (bottom). (Reproduced from Fig. 4, Urist, M. R., Mazet, R. W., Jr., and Bechtol, C. O., Amer. Surg. **25:** 883–890, 1959, with permission of the publisher.)

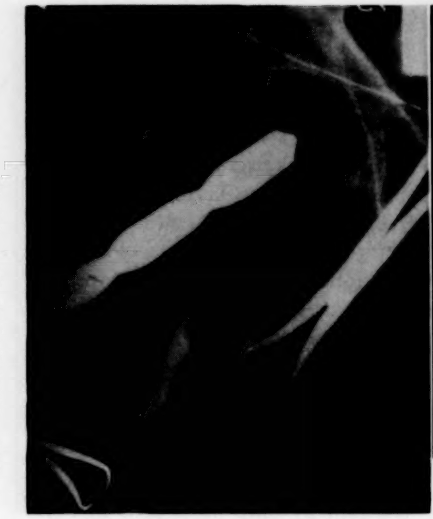

FIG. 4-A

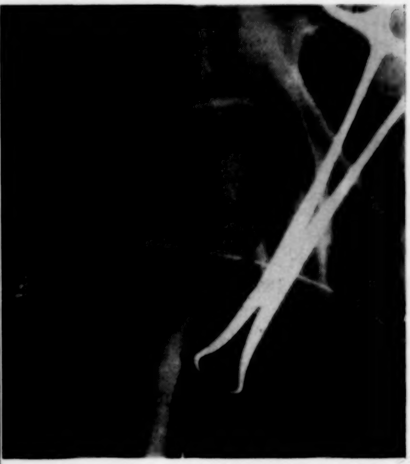

FIG. 4-B

FIG. 4-A. Roentgenogram of a subcapital fracture in the anteroposterior view showing drill point in the center of the head.

FIG. 4-B. Roentgenogram of a subcapital fracture in the anteroposterior view transfixed with a Collapatite peg. This peg was made from the crest of the tibia removed under sterile conditions from a human autopsy subject.

For use in Cases Nos. 10 to 20, the method of preparation was as follows: (1) acetone for twenty-four hours, (2) 8 per cent urea for twenty-four hours, (3) 8.8 per cent saline and agitation or a shaking machine for twenty-four hours, (4) 1 per cent Beta propriolactone, in a $NaCl \cdot NaHCO$ buffer at 4°C for forty-eight hours for sterilization, (5) wash in distilled water for twenty-four hours, (6) storage in sterile vials after drying in an oven (Fig. 3).

A third group of ten cases is now under treatment with Collapatite prepared by another protein solvent in place of urea and alternative sterilization procedures that may not reduce the mechanical strength of the tissue.

Collapatite prepared from cortical bone, after drying, as obtained by both methods described above, had the tensile strength, bending, and torsion resistance approximately that of oak wood. The tests for breaking strength, and comparisons with steel, are summarized in Table I. Bovine Collapatite was superior to human Collapatite in breaking strength. When used as a massive rectangular-shaped peg in the interior of the femoral neck, *if the fracture was reduced*, Collapatite was sufficiently strong for internal fixation of the hips. The peg was as wide as the combined trifin nail and a fibula and filled the hollow osteoporotic neck of the femur in one plane. In the other plane, half of the volume of the neck remained open for growth of callus and new bone.

Collapatite was very slowly absorbable and well tolerated by the tissues.

Experiments with this material as compared with various other materials implanted in the head of the tibia of dogs and rabbits have been completed and found to show that Collapatite is not incorporated as rapidly as autogenous bone, but it is invaded by new bone from the host bed at four to six weeks. The operations of past years with beef bone, *Os Purum*, and other heterogenous materials, gave similar results but never gained acceptance presumably because: (a) biological material has never been as readily available as metal for clinical trial, (b) metal was mechanically more reliable, (c) antigenic proteins were believed to cause undesirable inflammatory reactions. Collapatite represents an attempt to overcome these difficulties. Maximum contact compression of the fracture treated with this material was necessary, however, because, like metal, the peg can break if the fracture fails to heal.

Surgical Technic: The procedure for insertion of the peg was the same as employed for the Smith-Petersen trifin nail, except that a 1.0 cm. drill point was introduced for a guide into and through the center of the femoral head. A channel through the femoral head was absolutely essential; the trajectorial spongiosa was brittle, yet so hard that the peg would not enter the center of the head without preliminary construction of a passage. The opening in the lateral femoral cortex was enlarged with a rongeur to form a slot. First, the drill point and, later, the peg must be inserted under direct vision. Blind pegging, controlled with the

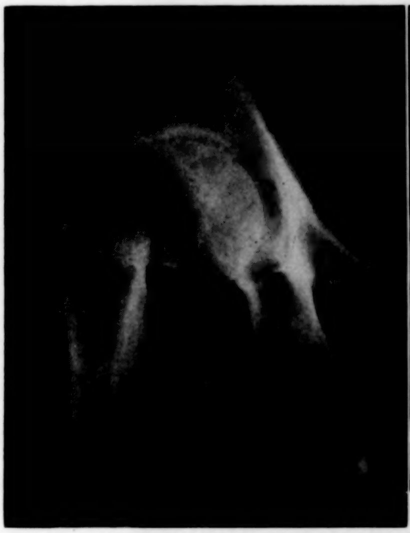

FIG. 4-C

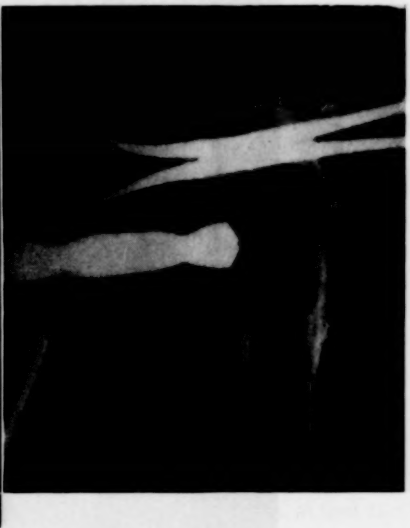

FIG. 4-D

FIG. 4-C. Roentgenogram of the fracture shown in Figs. 4-A and 4-B in the lateral view showing the displacement of the original fracture.

FIG. 4-D. Roentgenogram of the fracture shown in Figs. 4-A and 4-B in the lateral view showing the fracture reduced, the drill point in place, and the splintered posterior cortex.

aid of two x-ray units, may be attempted in easily-reduced and securely-held fractures. As emphasized by D. King, *et al.* (8), fractured hips should not be flexed to obtain the lateral view during blind nailing or pegging operations. To obtain good contact compression, the *neck should be telescoped inside the head* with the aid of a broad impactor with a curved surface that conforms to the cortex of the shaft of the femur. In some instances, to produce telescoping, it is necessary to remove a small amount of cancellous bone from the interior of the rim of the femoral head. This step eliminates any necessity to use force to produce impaction (Figs. 4 to 6).

Removal of the Peg: The peg was cut off at the base with a Gigli saw, allowing 1.0 cm. of the length to protrude from the opening lateral cortex. If it becomes necessary to remove the peg, this can be done with a bone-holding clamp or by drilling a hole in the protruding end and by introducing a standard instrument used for removing the Küntscher nail.

Interim Results: The follow-up results of the fracture were determined and recorded after a period of more than two years postoperative in ten cases treated with either human or bovine bone for internal fixation (Table II). The fracture

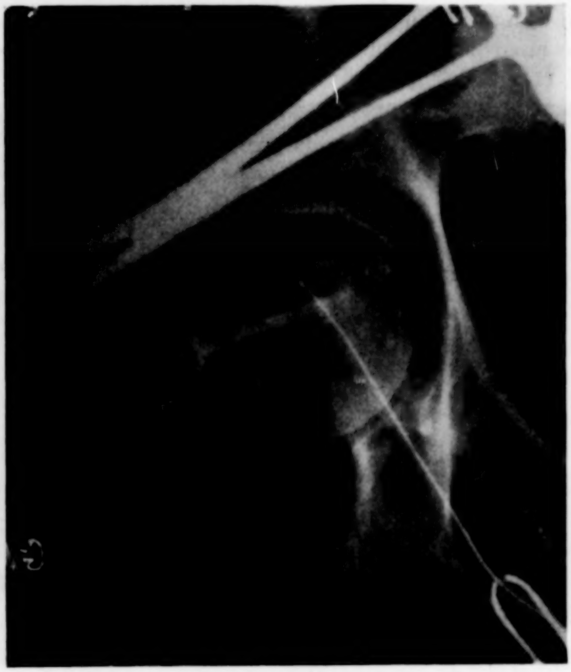

FIG. 4-E

FIG. 4-E. Roentgenogram in the lateral view of the fracture shown in Figs. 4-A to 4-C, with the Collapatite peg in place, and the fragments of the posterior aspect of the neck of the femur in correct alignment.

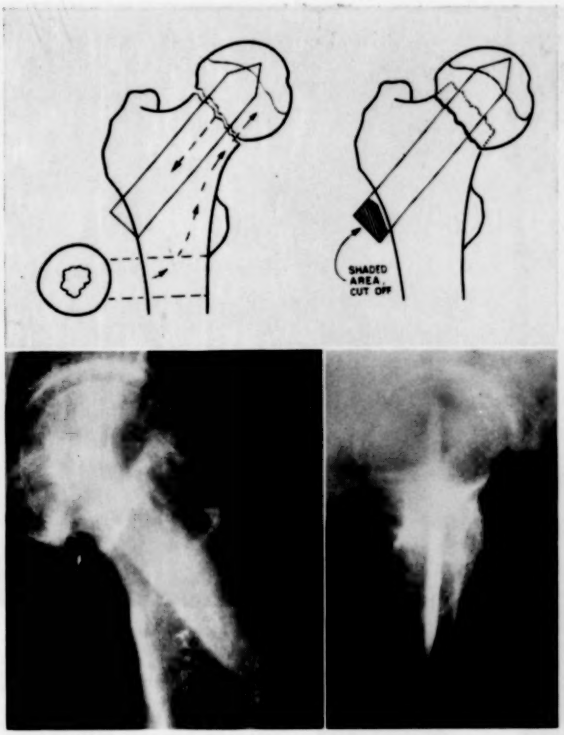

FIG. 5. Diagrams showing the position of the Collapatite Peg before (upper left) and after (upper right) impaction. Roentgenograms showing a subcapital fracture in a seventy-six-year-old woman (Case 8) after open reduction and internal fixation with a Collapatite peg made from human cortical bone, showing the femoral neck driven inside the base of the head by impaction; antero-posterior view, left; lateral view, right.

united in seven and the patients were able to walk without crutches before the end of the first year; three patients died of malignancy or cardiovascular disorders of advanced age. An autopsy was performed in one and the specimens of the healing fracture and peg were recovered for study.

A second series of ten cases were treated with bovine Collapatite (Squibb) and one-year results were determined and recorded in Table III. The fracture was accurately reduced and excellent fixation was obtained in all instances. Two patients were psychotic, however, and bore full weight on the fracture one day after the operation; one of these developed a hematoma in the wound and a postoperative infection; the other suffered no ill effects.

Although the numbers of patients are few, and although senile osteoporotic individuals frequently do not live five years, or the time necessary to obtain true end-results, our impression is that Collapatite has some advantages and can be used as a substitute for metallic appliances for internal fixation of subcapital fractures (Figs. 7 to 10).

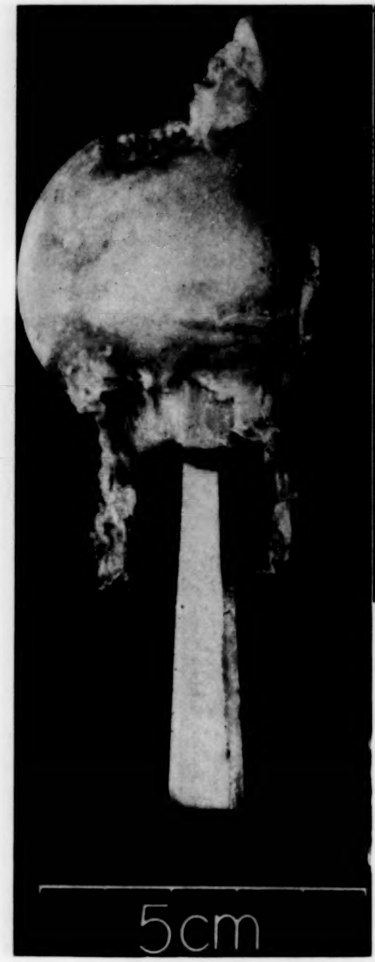

FIG. 6-A

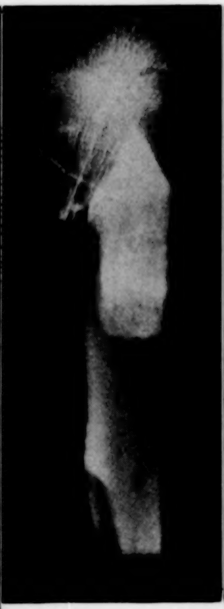

FIG. 6-B

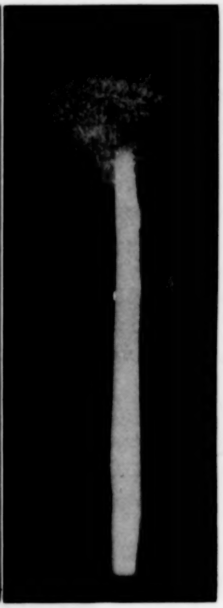

FIG. 6-C

FIG. 6-A. Photograph of the lateral view of a dissection of the femoral head from an autopsy subject with severe osteoporosis. Note the correct position of the Collapatite peg and the large amount of space in the hollow interior of the femoral neck.

FIG. 6-B. Roentgenogram of the specimen shown in Fig. 6-A. Note the extreme porosity of the bone of the cortex and the insufficient amount of cancellous bone in the femoral neck.

FIG. 6-C. Roentgenogram of the specimen shown in Figs. 6-A and B showing that if the peg is inserted into the head, without preparing it with a drill-point channel, the point will slide outside the trabecular stress lines and come to occupy an undesirable eccentric position.

DISCUSSION

In 200 articles on the surgery of fracture of the hip, published in English, French, and German languages during the past twenty-five years, postmenopausal or senile osteoporosis has been mentioned by only eleven writers, and in not one of these instances has an effort been made to treat patients with this disorder with special precautions or methods. Linton (10), Gray (6), and Scheck (14), emphasized the poor prognosis in patients with comminuted fractures but

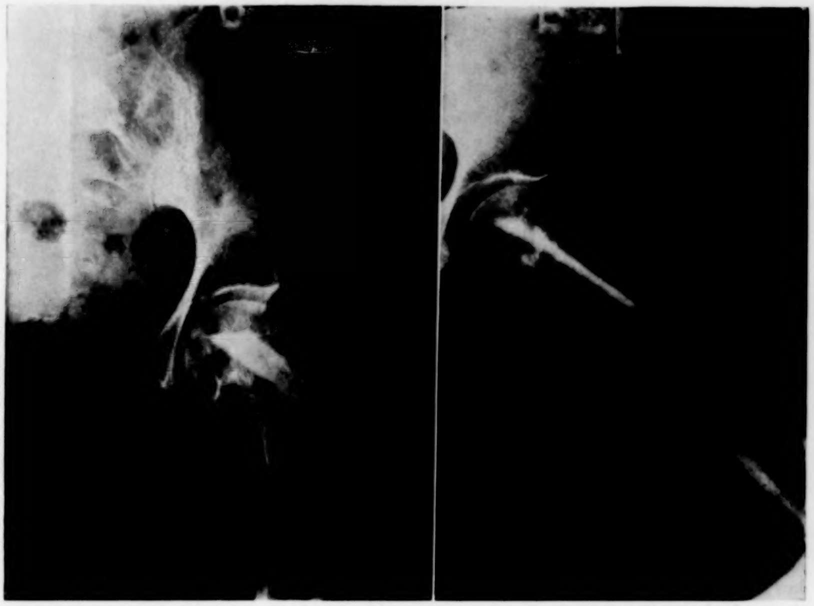

FIG. 7-A FIG. 7-B

FIG. 7-A. Roentgenogram in the anteroposterior view of subcapital fracture in a seventy-four-year-old woman, two years after injury, showing a bovine Collapatite peg incorporated in the neck of the femur.

FIG. 7-B. Roentgenogram of the same hip as shown in Fig. 7-A, in the lateral view, showing the peg in the correct position. Note the tilting of the femoral head due to resorption of the posterior wall of the femoral neck, immobilization, and solid union despite the unfavorable mechanical conditions.

did not associate this type of hip injury with osteoporosis. T. King (9) observed softening of the neck, mottling of the head with islands of fat, and increased vascularity of the trochanter due to "unknown cause"; he did not recognize the existence of osteoporosis, but he noted that these fractures were pathological, caused nail slippage, and responded poorly to open treatment. Ghormley (5), however, recognized osteoporosis as an entity and warned that it was a contraindication to the use of a hip prosthesis. Schmorl (15) recognized fracture of the hip as a manifestation of senile osteoporosis in a special article in 1924.

Our observations suggest that in osteoporosis, fractures of the femoral neck were almost always comminuted fractures. When metal was used for internal fixation, the appliance did not immobilize the fracture, the bone crumbled, and was resorbed; the result was a failure in approximately 50 per cent of the patients. The effort to substitute biological materials for metal is not new. In 1912, Albee (1) recommended autogenous massive grafts of the fibula in hip-nailing operations. Borelius (2) before, and Hey Groves (7), Gallie (4), and Luck (11),

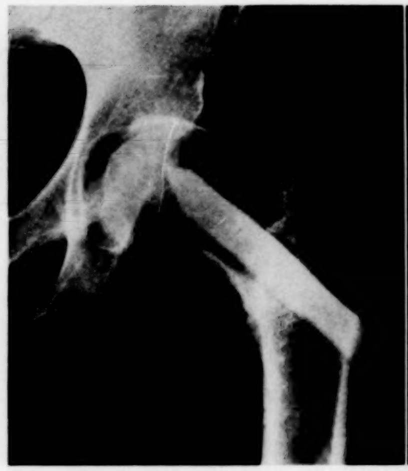

FIG. 8-A

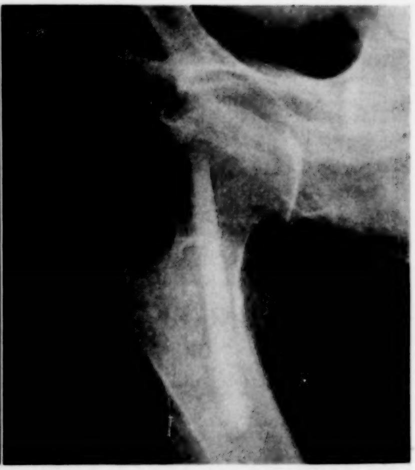

FIG 8-B

FIG. 8-A. Roentgenogram showing a united fracture of the base of the neck in a sixty-eight-year-old woman, two years after internal fixation, with a Collapatite peg. In the hollow trochanteric area, but not the head, the host demarcates the Collapatite by a fibrous line and a layer of new bone.

FIG. 8-B. Roentgenogram of the lateral view of the same case as shown in Fig. 8-A. Note the formation of new trabecular bone on the surface of the Collapatite inside the head of the femur.

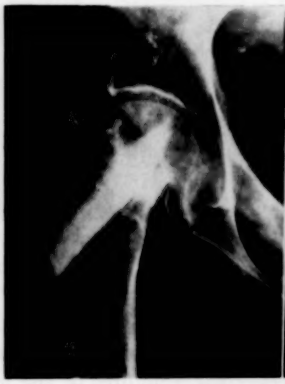

FIG. 9-A

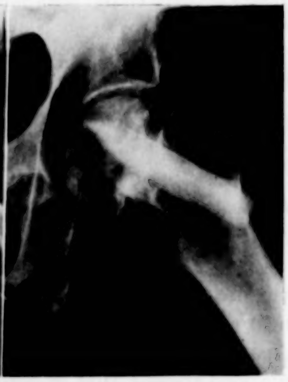

FIG. 9-B

FIG. 9-A. Subcapital fracture in a 74 year old woman, antero-posterior view, 2 years after internal fixation with a Collapatite peg. Note the neck telescoped inside head for a distance of 1.0 cm.

FIG. 9-B. Lateral view of the same case as shown in figure 9-A. Note the line of demarcation between the Collapatite and the wall of new bone laid down by the host in the hollow trochanter but not the spongiosa of the head.

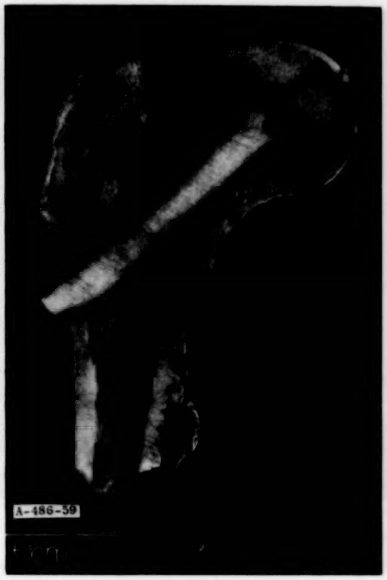

FIG. 10-A

FIG. 10-A. Autopsy specimen of Collapatite peg in a healed mid-cervical fracture of the femur. The patient died of chronic heart disease, following an extensive bowel resection, six weeks after the operation. Note the mottled head and thin cortex of the neck of the femur. No absorption around peg.

after Albee, used modifications of the peg and the technic of the operation. Watson-Jones (20) and Patrick (13) found that the fibula was not strong enough to be relied upon for internal fixation and recommended the method of King (9) who perfected a trifin-nail-fibular transplant operation. Hey Groves (7) actually preferred beef bone to an autograft because it was absorbed slower than fresh autografts of fibula.

Availability, structural strength, and the desire to spare the patient from multiple surgical incisions to obtain an autograft is responsible, to a considerable measure, for current preference for metal for internal fixation of fractures. It is not necessary, however, to use metal in every case. For osteoporotic hips, occurring in the increasing numbers of aged patients, a derivative of bone, such as Collapatite, can be made available and stored in any hospital for indefinite periods of time. Orell (12) prepared a similar material, *Os Purum*, by cleaning calf bone and soaking it in salt solution and warm potassium hydroxide to remove all proteins, and then in acetone to remove fat. Orell, and many others who followed him, made the mistake of employing *Os Purum* as if it were a substitute for a bone graft, and its use gradually fell into disrepute in many clinics. Collapatite is essentially the same material as *Os Purum*, except that it is generally prepared from bovine or human autopsy bone by use of urea to obtain selective

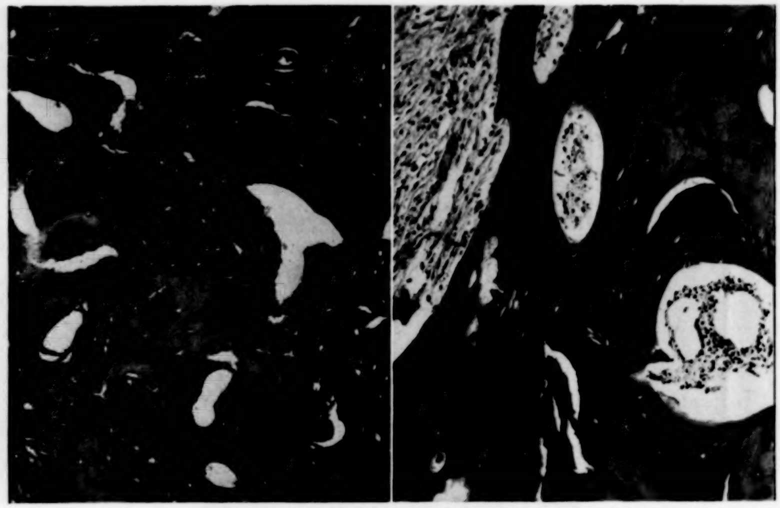

FIG. 10-B FIG. 10-C

FIG. 10-B. Histological section of Collapatite. Note the empty lacunae following extraction of the intracellular protein, and the shrinkage cracks in some of the interstitial lamellae.

FIG. 10-C. Histological section of the tip of the Collapatite peg in the center of the femoral head. The new bone growing into the Collapatite, contains osteocytes and appears in the center of the picture. The Collapatite contains no osteocytes or cell debris and appears in the lower left and upper right corners of the picture. The cement line demarcates the dividing line between the host new bone and the Collapatite.

extraction of noncollagenous proteins and other antigens. But, most important, it is necessary to emphasize that Collapatite is not *bone* but a derivative of bone; it should never be used for a bone graft but only as a substitute for metal. Nevertheless, Collapatite is a replaceable, relatively nonirritating substance. It is superior to metal for fixation of brittle osteoporotic bone because it fills the femoral neck and provides internal cohesiveness. Unlike metal, Collapatite is not enveloped permanently in fibrous tissue; when it is invaded by new bone from the host, it is attached to the skeleton by cement substance (16).

Collapatite, like other processed proteinaceous material, such as catgut, or silk thread, appears to be relatively free of risk. Homogenous and heterogenous cortical bone, without preliminary chemical extraction of antigenic proteins, may call forth deleterious tissue reactions from the host. By means of a process such as that employed in the production of Collapatite, biological materials may be made less hazardous and more useful for internal fixation of fractures of the future.

SUMMARY

1. Preoperative lateral view roentgenograms of the dorsal and lumbar spine should be examined in every case of fracture of the hip. Patients showing col-

lapsed vertebrae in the dorsal spine, "ballooned" intervertebral discs in the lumbar spine, thin cortex on the vertebral bodies throughout the spine, and other gross evidence of postmenopausal or senile osteoporosis, should be either managed by closed methods or advised to have surgical treatment only with great caution.

2. Patients with fractures of the hip associated with osteoporosis of the spine can develop serious complications in at least 50 per cent of the cases, compared with 30 per cent or less in non-osteoporotic individuals.

3. In osteoporotic patients, it is especially important that the fracture be impacted by telescoping the neck into the head in order to obtain maximum contact compression.

4. Collapatite, a derivative of human or bovine cortical bone, was employed as a substitute of metal. Twenty osteoporotic hips were treated by open reduction and internal fixation with Collapatite pegs in an attempt to improve the poor end-results of subcapital fractures. Ten cases examined after two years showed union in seven, and three died of unrelated intercurrent disease. Ten additional cases examined one year after the injury showed union in seven, poor healing in one, and two died of heart disease. Observations on a large number of cases are required to draw further conclusions about the value of Collapatite for the treatment of osteoporotic hips.

ACKNOWLEDGEMENT

The authors are indebted to Dr. James Dingwall of the Squibb Institute for Medical Research for the sterile-collected lyophilized calf bone and to Captain George Hyatt, U.S.N. Medical Corps, Chief of the Tissue Bank, for the sterile-collected lyophilized human bone, used in Cases Nos. 1 to 10. Collapatite used in Cases Nos. 10 to 20 was prepared in the laboratories of James Dingwall, M.D., and Wayne Wescott at Squibb Institute, New Brunswick, N. J.

REFERENCES

1. Albee, F. and Preston, R. L. *Injuries and Diseases of the Hip*, pp. 39–47. P. B. Hoeber, Inc., New York, 1937.
2. Bick, E. M. *Source Book of Orthopedics*, Williams & Wilkins, Baltimore, 1948.
3. Borelius: Quoted by Bick (2).
4. Gallie, W. E. The use of boiled bone in operative surgery. Ann. J. Orth. Surg., **16:** 373–383, 1918.
5. Ghormley, R. K. Complications of hip prosthesis arthroplasty: osteoporosis. Instructional Course Lectures. Am. Acad. Orth. Surg., **15:** 32, 1958.
6. Gray, C. H. Fractures of the neck of the femur. Chapter 11. *Modern Trends in Orthopedics*. H. Platt, editor. P. E. Hoeber, Inc., New York, 1956.
7. Hey Groves, E. W. The treatment of the fractured neck of the femur with especial regard to the results. J. Bone and Joint Surg., **12:** 1–11, 1930.
8. King, D., Leef, E. and Terwilliger, C. K. The importance of accurate roentgenography and interpretation in femoral-neck fractures treated by internal fixation. J. Bone and Joint Surg., **22:** 168–170, 1940.
9. King, T. Closed operation for fracture of neck of the femur—final results in recent and old cases. Brit. J. Surg., **26:** 721–748, 1938–39.
10. Linton, P. Types of displacement in fractures of the femoral neck. J. Bone and Joint Surg., **31-B:** 184–189, 1949.

11. Luck, J. V. Intracapsular fracture of the neck of the femur. J. Bone and Joint Surg., **17:** 332–337, 1935.

12. Orell, S. Studien über knochenimplantation and knochenneubildung, implantation von "Os Purem" Sowie Transplantation von "Os Novum". Acta Chir. Scandinav. (Suppl. 31) **74:** 1–274, 1934.

13. Patrick, J. Intracapsular fractures of the femur treated with a combined Smith-Petersen nail and fibular graft. J. Bone and Joint Surg., **31-A:** 67–80, 1949.

14. Scheck, M.: Unstable internal fixation of intracapsular fractures of the neck of the femur of the adduction type. J. Bone and Joint Surg., **41-A:** 558, 1959.

15. Schmorl, G. Die pathologische anatomie der schenkelhalsfrakturen. Zentralbl. f. Chir., **51:** 2388–2391, 1924.

16. Urist, J., MacDonald, N. S. and Jowsey, Jr. The function of the donor tissue in experimental operations with radioactive bone grafts. Ann. Surg., **147:** 129–145, 1958.

17. Urist, M. R. The etiology of osteoporosis. (Guest Editorial) J.A.M.A., **169:** 710–712, 1959.

18. Urist, M. R. Observations bearing on the problem of osteoporosis. *Bone as a Tissue.* K. Rodahl, editor. Blakiston Division, McGraw-Hill, New York, 1960.

19. Urist, M. R., Mazet, R. W., Jr. and Bechtol, C. Senile osteoporosis as a disorder influencing treatment and end results of fractures of the hip. Am. Surgeon, **25:** 883–890, 1959.

20. Watson-Jones, R. *Fractures and Joint Injuries,* 4th ed., p. 713, Williams & Wilkins, Baltimore, 1955.

DISCUSSION

Dr. George J. Curry (Flint, Michigan): My first comments will be in connection with Presentation No. 9. I don't know why I was asked to discuss this, because I don't know anything about it. I never heard of Collapatite until I read Marshall Urist's paper, but I am interested, as are all of you, in the subject of osteoporosis.

I believe that the contents of Dr. Urist's presentation were very well done, and emphasize the frequent occurrence of osteoporosis. Associated fractures of the spine have been observed by our group. We have not made it a routine to have radiograms of the spine; perhaps the principal reason being that it is quite painful for the patient to be turned on the side for a film. Technical difficulties are obvious in obtaining lateral films of the patient in the supine position.

Dr. Urist's discussion of Collapatite as a substitute for metallic units in these cases is most interesting. We have known for a long time that an osteoporotic bone does not tolerate metal well. To facilitate nail insertion we have routinely used guide pins, which obviates the repeated nail insertions that further traumatize inferior bone.

It is rather astonishing to note that in osteoporotic bone, the cortical thickness is one-third that of the non-porotic bone. I didn't know that there was such a large percentage. I did not think that the incidence of poor results from metal inserts was as high as 50 per cent.

Posterior splitting of the femoral head has been observed with the use of metallic units, and this obviously produces a poor fixation. We have noticed the ease with which a metallic unit may migrate anteriorly or superiorly in a femoral head that is osteoporotic.

We have made it a policy to individualize the case in which a hip prosthesis is used. The presence of osteoporosis in the acetabulum makes this procedure questionable. I am further astonished to hear that 84 per cent collapsed vertebrae are found in these cases with ununited subcapital hip fractures in the osteoporotic. We have felt for a long time that the fracture occurs first and the patient falls as a result. When there is a direct injury it is more apt to be an intertrochanteric fracture.

It is very obvious that non-metallic material is better. Ordinary metallic units do not fill the femoral neck. We have observed this for a long time. They are too small.

Telescoping is a new procedure, Dr. Urist, and I think it is very commendable. I have always been interested in anything that you have ever done in your life, because as an investigator you are very painstaking and thorough. Any conclusion that you arrive at must be listened to, and I am sure the clinical investigation that you have started will continue.

DR. MARSHALL R. URIST (Closing) (Los Angeles, California): I wish to take this opportunity to thank Dr. Curry for his very kind discussion.

He raised two important points. First, the pain in turning a patient to obtain a lateral spine film on a patient with a fractured hip. It is true that this is uncomfortable, but when we put a pillow between the patient's knees and the doctor himself turns the patient on the sound hip, there is only minimal pain and we believe the information that is gained is worth the effort.

If the lateral spine films show ballooned discs and many collapsed vertebrae, the outlook for a nail holding in the neck of the femur is very poor. As we have noted, in 50 per cent of the cases in the hands of a skillful surgeon, the result was satisfactory. The other 50 per cent of the cases had complications that the average surgeon cannot avoid. These were associated with splintering of the posterior cortex.

Dr. Curry emphasized the value of using blind nailing, and we agree that it is best for some fractures. An experienced surgeon can anticipate a difficult nailing operation from the x-ray examination especially after he has done a Leadbetter maneuver and reduced the hip. If there is a lot of splintering of the posterior cortex, and if it is a high subcapital fracture, he will often save time by doing an open operation. On the other hand, if it is mid-cervical or basal neck, he will generally succeed with blind nailing and obtain an excellent result. We use a cannulated drill point, designed by Collison, for a guide wire for the purpose.

Another very important point to emphasize about osteoporosis of the hip is that there is only one place in the femoral head that you can trust. This place is the very center where the trabeculations cross. The bone where the stress lines cross is more firm than in any place else; if the nail is lodged in the upper or anterior quadrant it will not hold as well as if it is placed "dead center".

I see my teacher, Dr. Henry Marble of Boston sitting in the first row. He taught the surgical procedure of hip nailing on fresh cadavers in the morgue. As house officers, we did the operation by inserting straws in the femoral neck through a small drill hole, 1¼″ distal to the externus tubercle of the greater trochanter and we aimed for the center of the head. By a dissection after the operation, we learned the landmarks and the pitfalls of the procedure. I recommend Dr. Marble's methods of teaching to you and your students.

THE EFFECT OF SHOCK ON THE LUNG

(A Preliminary Report)

JAMES C. DRYE, M.D., EUGENE H. CONNER, M.D.
AND NORTON G. WATERMAN, M.D.

From the Department of Surgery and Section on Anesthesiology of the University of Louisville School of Medicine

Shock is almost impossible to define. However, as we surgeons see it, it is associated with severe injury or following extensive surgery. Many of the abnormal physiological changes which accompany shock have been carefully studied and much has been learned. These include the acute changes such as those associated with reduced blood volume, and the later sequelae such as "lower nephron nephrosis," changes of liver function and effects on the endocrine glands.

In spite of this mass of knowledge, many of our patients who have had no vital organs injured and in whom the acute abnormalities such as reduced blood volume, have been corrected, die. Why do these patients die? Autopsy in most cases does not satisfactorily reveal the cause of death. We hear residents and others say, "the bottom dropped out," "he was hit too hard," "he was all flaked out," and so forth. In many cases pulmonary insufficiency plays a major role. The pulmonary insufficiency is often due to retained secretions with resultant atelectasis. If there is a concomitant chest injury, the wet lung syndrome as described by Burford and Burbank (1) may be present.

Due largely to experience and knowledge gained in World War II, the problems related to obstructive and compression atelectasis, flail chest, hemopneumothorax and the wet lung syndrome became well understood and logical, effective therapy became standardized. In spite of the most strenuous efforts directed toward correction of these difficulties, the patient, if he survives two or three days, may die of what appears to be pulmonary insufficiency. This may occur even when there has been no direct chest injury. Why? Is something other than the above changes going on in these lungs?

There has been a good deal of experimental work on the effects of shock on such organs as the kidney, liver, heart and the endocrine glands. Little has been done on the effect of shock on the lung.

For these reasons we have thought that a new look, perhaps an "agonizing reappraisal" of this problem is needed. Is there a specific effect of shock on the lung; an effect other than that of obstructive or compression atelectasis, or retained secretions?

During World War II the senior author performed a number of autopsies on

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severely wounded soldiers who had been treated in the field hospitals by surgeons in the 2nd Auxiliary Surgical Group. In many cases these men had survived two to four days and had had intensive anti-shock therapy. The autopsies on some of these soldiers, even those who had no chest injuries, showed that the lungs were large, heavy, airless and hemorrhagic. Cut section closely resembled the appearance of a cut section of liver. Bronchial secretions did not seem to be greatly increased. Under wartime conditions, microscopic studies were not made.

Similar findings have been observed at the Louisville General Hospital in patients who have had severe traffic injuries.

Microscopic observations are extremely difficult to interpret. The histological appearance of lung tissue varies greatly with the technique of fixation and the way the lung is handled before fixation. If the chest is opened before the trachea is clamped outside the chest and the lung allowed to collapse and then fixed, the histological picture is entirely different than if the lung is fixed in an inflated state. Many other variables in the technical preparation of lung tissue for microscopic examination may cause entirely different histological appearances.

In spite of these difficulties, there appears to be a true difference between the histological characteristics of simple obstructive or compressive atelectasis and the picture seen in lungs of patients who have been subjected to prolonged severe shock. In the latter condition one frequently finds severe vascular congestion similar to that seen in heart failure and after rapid decompression (2). This has been described by Jenkins, Jones, Wilson and Moyer and termed "congestive atelectasis." They produced it by tourniquet shock and rapid infusion of saline (3).

It is characterized by marked capillary and arteriolar dilatation, a great increase in the number of red cells in the capillaries, compression of the alveoli and a degree of edema which is usually minimal (Fig. 1).

From our studies in the human and the animal we doubt that much more can be learned from pathological observations. Physiological studies such as determination of pulmonary vascular pressures, pulmonary blood flow, compliance studies and so on are needed. To this end we have turned to animal experiments. To date our findings have been inconclusive. We have studied the changes in approximately 40 dogs.

We have attempted to produce pathological and physiological changes in the lung by tourniquet shock. Occlusive tourniquets were placed on both hind legs. They were left in place for periods of 2 to 5 hours and then suddenly released. Observations were made till the death of the animal or for periods of 2 to 3 days and the animal then sacrificed. The effect on the animals has been variable. Some have died in a few hours after occlusive periods of only one or two hours. Others have survived five or six hours of occlusion and have shown little effect except for local swelling.

The gross and microscopic effects on lungs have been inconstant. Some developed definite changes similar to those which have been observed in humans, i.e., heavy, red airless lungs, which on cut section resembled liver tissue. The typical histological changes are shown in Figure 2.

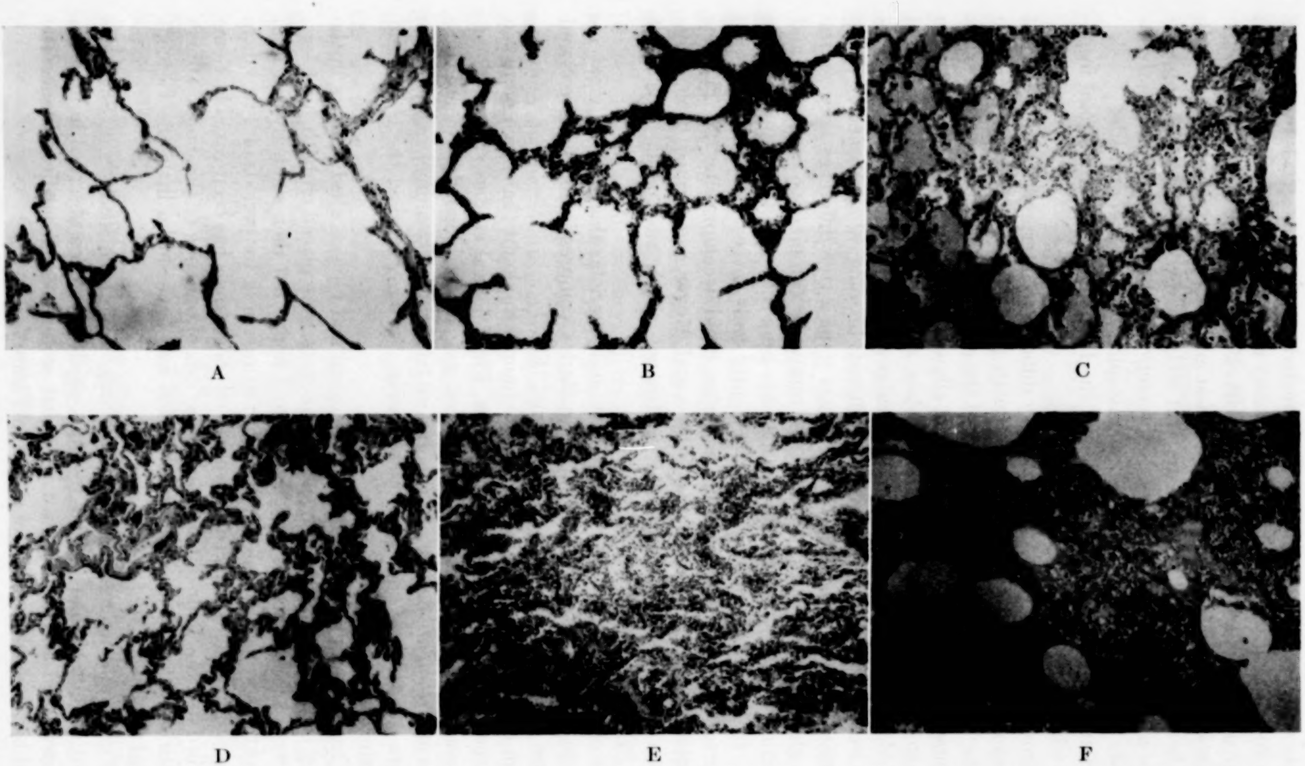

FIG. 1. A. Normal human lung. B thru F. Varying degrees of congestion, edema, and obliteration of air sacs occurring in patients after prolonged shock.

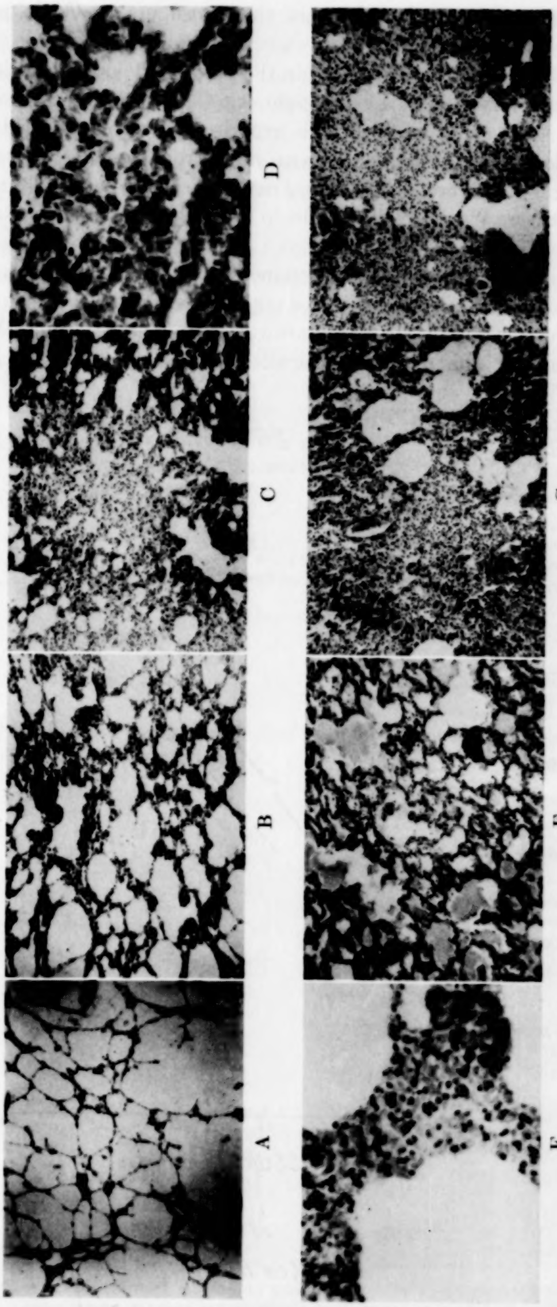

FIG. 2. A. Normal dog lung fixed in inflated state. B. Normal dog lung fixed after lung allowed to collapse postmortem. C thru H. Varying degree of congestion, edema and obliteration of air sacs after shock.

We attempted to study the effects of the tourniquet shock on pulmonary artery, left atrial and carotid artery pressures and on lung compliance in the dog.

Small polyethylene tubes were placed in the pulmonary artery, the left atrium and the carotid artery. These were brought out through the chest wall and arranged so that they could be filled with heparin, tied off and buried in a subcutaneous pocket and the ends withdrawn at appropriate times hours or days later. Pressures were recorded from these catheters by use of strain gauges and electronic recorders. We have been able to keep these tubes open for a week or more.

Pulmonary compliance has been determined either by injecting a known volume of air through an endotracheal tube and measuring the pressure or the reverse procedure of injecting air to a known pressure and recording the volume of expired air on a spirometer. A few animals have shown an increase in stiffness of the lung (Fig. 3).

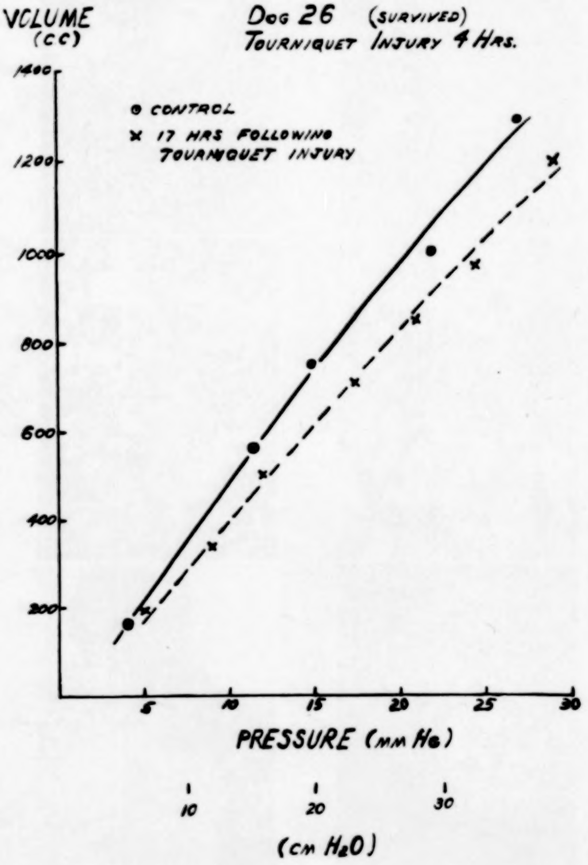

FIG. 3. Effect of tourniquet shock on pulmonary compliance

More recently we have been using a more physiological method. A balloon is fitted on a catheter and placed in the pleural cavity. The catheter is arranged so that the end can be buried in the subcutaneous pocket, withdrawn at appropriate times. It is attached to a strain gauge and pressures recorded. These pressures are recorded simultaneously with the tidal air volumes as recorded on our spirometer. The ratio of force required to remove a volume of air can be derived. The more force needed to move a given volume of air should make the lung stiffer—i.e. there is less compliance.

On release of the tourniquet we found an abrupt drop in the carotid artery pressure, a rise in the pulmonary artery pressure and the drop in the left atrial pressure. This observation confirms that of Jenkins, Jones, Wilson and Moyer (3).

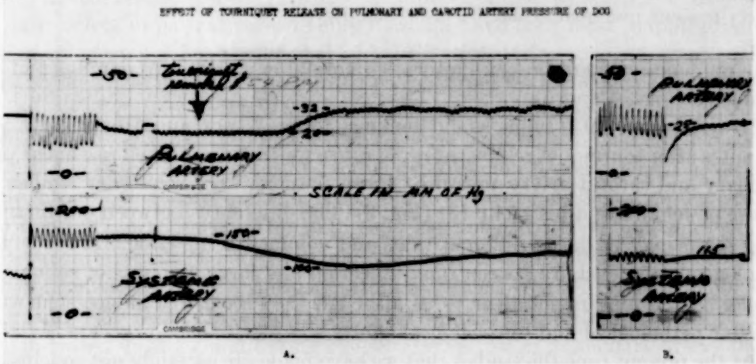

FIG. 4. Tourniquets applied to both hind legs for 5 hours then released. A. Immediate effect. B. 24 hours after release.

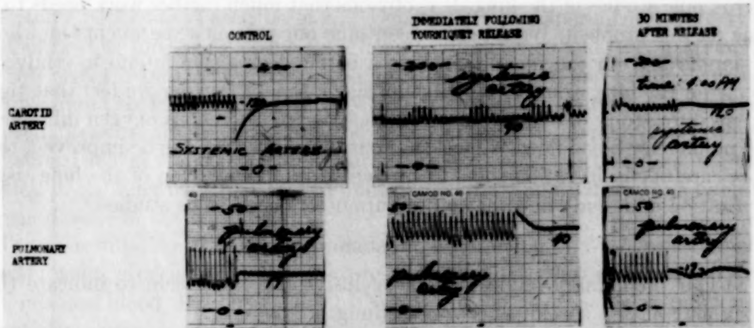

FIG. 5. Effect of tourniquet release on pulmonary artery, pulmonary vein and carotid artery pressure. Tourniquet applied for 5 hours to both hind legs.

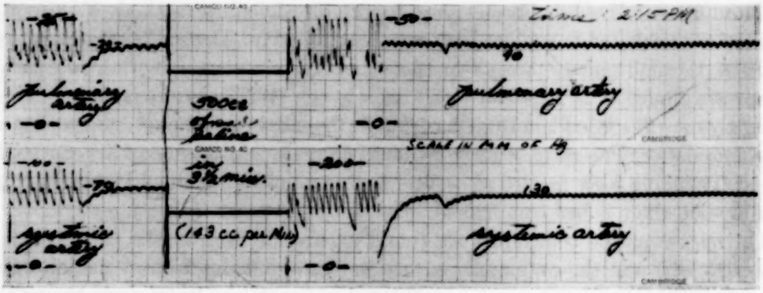

FIG. 6. Effect of injection of 0.9% saline, 500 ml. at rate of 143 ml. per minute. Note scale factor change on right part of record. Pulmonary artery pressure doubled and carotid artery pressure rose from 70 mm. Hg to 130 mm. Hg.

The pulmonary artery pressure returns to normal in a matter of minutes and remains so (Figs. 4 and 5).

If we injected 0.9% saline as did Jenkins, Jones, Wilson and Moyer (3), a few minutes after tourniquet release, at rapid rates, we found a marked rise in the pulmonary and carotid artery pressure. These findings were somewhat similar to those of Jenkins and his group (3) (Fig. 6). The differences between our findings and theirs may be due to different rates and volumes of injection. However, the etiological relationship between rapid injection and large amounts of saline and shock on the lung is not clear to us although they seem to produce somewhat similar pathological and physiological effects.

At the present time the studies that we have made are certainly not conclusive. However, they seem to indicate that shock does produce some changes in the lung. The most striking difference so far has been that found by gross and microscopic studies of the lung. It is obvious that much further work needs to be done on this problem. We intend to continue our present experiments and hope to standardize our tourniquet shock to a better degree. We intend to study the effects on the lung of irreversible hemorrhagic shock. Further we feel that there is a need for study of other parameters such as arterio-venous oxygen differences and pulmonary blood flow. We feel that our techniques need to be improved, that more careful consideration should be given to the preparation of the lung tissue for fixation and study and that other parameters need to be studied.

CONCLUSION

(1) Our preliminary studies are inconclusive but they seem to indicate that shock may have a specific effect on the lung.

(2) Gross and microscopic observations indicate that prolonged shock produces hyperemia, congestion and mild degree of pulmonary edema to the extent that a significant amount of pulmonary insufficiency may result.

REFERENCES

1. BURFORD, T. H. AND BURBANK, B. Traumatic wet lung; observations on certain physiologic fundamentals of thoracic trauma. J. Thoracic Surg., **14:** 415–424, 1945.

2. Fegler, J. and Banister, J. Congestive atelectasis in lungs of rabbits and other animals subjected to the action of low barometric pressure. Quart. J. Exper. Physiol., **33:** 291–309, 1944–46.

3. Jenkins, M. T., Jones, R. F., Wilson, B. and Moyer, C. A. Congestive atelectasis—complication of the intravenous infusion of fluids. Ann. Surg., **132:** 327–347, 1950.

DISCUSSION

Dr. Donald M. Glover (Cleveland, Ohio): I can only express admiration for the very fine work that Dr. Drye presented, which is on a most pertinent subject, and I sincerely hope that he will continue to elucidate that problem, which is one that we are all very much interested in and would like to know the final answer.

Dr. Fraser N. Gurd (Montreal, Quebec, Canada): During the past two and a half days numerous papers dealing with mortality in multiple and extensive injury have made note of the fact that the failures in therapy seemed attributable to some defect in patient care. I think it would have been most inappropriate if this meeting were to have concluded without a presentation to focus our attention back to the resuscitation of the injured patient from a state of shock.

I am very grateful to Dr. Drye for raising the question of the lung in shock once again. It is almost the lung's turn to come back into the picture. I made a little list of systems and organs of the body, anatomical areas, which have had their turn at being fashionable for study by shock people in the last twelve years, and I jotted down sixteen. The lung really has not had a good "go" since 1950.

Between '47 and '50, however, quite a number of people studied the lung, partly stimulated by a very fine paper from St. Louis by R. M. Eaton (J. Thoracic Surg. **16:** 668, 1947). He won the Thoracic Surgical Association prize for it. He demonstrated in shock and during resuscitation a rise in pulmonary artery pressure and an increase in pulmonary lymph flow. This was followed soon after by the Wilson and Moyer work on "Congestive Atelectasis," to which Dr. Drye has referred.

Eaton's paper stimulated us in the Department of Experimental Surgery at McGill, and we did the following experiments during shock and resuscitation. We catheterized the pulmonary artery and also the left atrium and pulmonary vein, and we found that the circumstances which produced an elevation of pulmonary arterial pressure almost simultaneously produced a rise in pulmonary venous pressure. I felt at the conclusion of our year's work that the blame for the congestion in the lung had to be placed upon the myocardium, rather than upon intrinsic disease in the lung itself.

To get results like this you have to have your timing of your measurements exactly right, especially in relation to resuscitative procedures such as infusions of fluids and blood. Dr. Drye and Dr. Moyer did not get this rise in pulmonary venous pressure.

There is considerable other evidence that in severe shock, and particularly after prolonged hypotension, the myocardium is adversely affected. There may be cardiac dilatation. There is a rise ultimately in peripheral venous pressure; that is, right arterial pressure, even in the presence of a low stroke output, which I think must bespeak a degree of myocardial failure. There is a decrease in coronary artery flow. There is spasm in the coronary vessels themselves at just the moment when a wide open flow is what is really needed. The E.C.G. changes in man and animals are well known.

However, Dr. Drye has reminded us again that this may not be the whole answer at all. In fact, he has brought forward evidence to bring up the question again of a distant adverse effect upon the lung as a result of something that is happening in the shock process. The fashion at the moment is centered around endotoxins and toxins of various sorts working in conjunction with and against the reticulo-endothelial system, and perhaps the lung is being affected by some mechanism such as that.

He has my sympathy with this type of material. It is extremely difficult to do and to interpret, and I would like to thank him and congratulate him for his courage in starting out on such a project.

President Stack: Dr. Drye, will you close?

Dr. James C. Drye (Louisville, Kentucky): I think we have only scratched the surface in this problem and there are many things to be answered.

Shock is always, in our hands, mixed up with intensive anti-shock therapy. Perhaps it is our therapy that is bringing these changes on. Dr. Gurd mentioned toxins. I talked about this problem with Dr. Warren Cole, and he thought there might be some toxin from degraded protein tissue and crushed muscle and so on perhaps causing this.

In our experiments the pulmonary artery pressure did go up and the pulmonary vein pressure went down. Dr. Moyer found about the same thing, and he was somewhat puzzled to explain this, because it shouldn't happen when we get congestion of the lung. I can't explain it either.

I would like to thank Dr. Glover for his kind remarks and Dr. Gurd for his discussion.

DIED IN HOSPITAL

A Three Year Study of Deaths Following Trauma

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This study is a review of therapeutic failures in a group of seriously injured soldiers during a three year period, 1957 to 1959. The Medical Statistics Division of the Surgeon General's Office records the admission of all injured Army personnel regardless of the location of their hospitalization and deaths are especially well documented. Arbitrarily only those cases were considered which arrived at a hospital alive and were seen by a physician, but who died within two weeks of their admission. No attempt was made to include those individuals killed outright or to consider all injuries during this period in relation to the epidemiology of injury. Every case in this limited group was included except the one member of the Womans Army Corps, who was excluded to avoid the variable of sex. An analysis has been made of the medical records of all of the 606 male soldiers who were in the above category. Their ages ranged from 18 to 55 years with an average age of 26½ (Table I). As far as could be determined, all had been in good health. The type of trauma did not differ markedly from other series (6) with moving vehicle accidents accounting for well over half of these critical injuries in soldiers as well as in the population at large (Table II). These cases were treated in all sizes and types of hospitals from small community or army post hospitals to large teaching centers both military and civilian. 207 were treated in civilian and 384 in military hospitals while 15 were treated in both.

FINDINGS

Speed in reaching medical attention did not seem a primary factor in survival of the injured (2). Although the interval between injury and admission could not be accurately determined in 15% of the cases, nevertheless at least 60% were in a hospital within an hour of injury and only 10% were delayed over 2 hours (Table III).

Clinical diagnoses were similar in numbers and distribution to other series (4) with a preponderance of head injuries (Table IV) but only 29% could be classified as multiple injuries. Considering the severity of the trauma this may reflect preoccupation with the obvious injuries rather than carefully recorded physical findings.

Read before the Twentieth Annual Session of The American Association for the Surgery of Trauma, Coronado, California, October 5–7, 1960.

* Formerly Chief Surgical Consultant to The Surgeon General, Department of the Army, Washington, D. C.

This material has been reviewed by the office of the Surgeon General, Department of the Army, and there is no objection to its presentation. This review does not imply any indorsement of the opinions advanced by the author.

TABLE I

Age Distribution

Age	Number
17–20	129
21–25	249
26–30	77
31–35	68
36–40	31
41–45	34
46–55	18
Total	606

Average age 26.5.

TABLE II

Type of Trauma

Moving vehicle	376
Gunshot wound	85
Falls	73
Burns	24
All other	48
Total	606

TABLE III

Interval Between Injury and Admission

	% of Cases
Less than ½ hour	20
½ Hour to 1 hour	40
1 Hour to 2 hours	15
Over 2 hours	10
Undetermined	15

Deaths from trauma are often condoned by the excuse that the patient died before anything could be done; however, in this series only 8% died within a half-hour after being seen by a doctor and less than 25% died within two hours of admission (Table V). In at least 75% of these cases therefore, the admitting physician had time to adequately appraise the injury and institute treatment. Autopsies were done on 516 of the 606 cases and it is apparent that the correlation between ante and post mortem diagnoses was far from perfect (Table VI).

Treatment varied widely, as perhaps it should, since there can be no "routine" treatment for injury cases, (Table VII) but it is noteworthy that in 246 cases, no treatment or its usual equivalent "supportive treatment" only was given and in this group, 75 were considered to be salvagable while an additional 69 might possibly have been saved with proper treatment (Table VIII).

TABLE IV

Clinical Diagnoses

Head injury	358
Skull fracture	248
Major fractures	127
Chest injury	126
Abdominal injury	97
Major lacerations	42
Spinal cord injury	36
Major vessel injury	30
Burns	24
"Shock"	60

TABLE V

Interval Between Admission and Death

	Cumulative %
½ Hour or less	8
2 Hours or less	24
12 Hours or less	57
24 Hours or less	70
3 Days or less	82
7 Days or less	88
14 Days or less	100

Overall results of treatment cannot be precisely stated. Admittedly, some hospital records are incomplete and inaccurate and hindsight from the autopsy table is far superior to clinical judgment in the emergency room. However, all cases were arbitrarily considered to have had adequate treatment if they met any one of the following criteria: were under a doctor's care for one half hour or less; were injured so seriously that their chance of survival would have been poor regardless of treatment; or had records which gave even the barest hint of proper treatment albeit the details were not recorded. For example, a patient with severe intracerebral damage was classified as adequately treated even though a pneumothorax had been completely overlooked. Likewise, a case of ruptured spleen was so classified when the record stated only that "blood was given." In spite of these liberal allowances, the records showed that overall treatment afforded these patients was inadequate by any criteria (Table IX).

ILLUSTRATIVE CASES

Case 1. J. C., a 26 year old white male, was admitted to a 250 bed hospital at 2:00 a.m. by police ambulance, with a history of having been the driver of a speeding car which struck a tree. The injury occurred approximately one hour prior to admission. On admission he was conscious, pale and apparently in considerable pain, localized in the lower chest and upper abdomen. Blood pressure was recorded at 120/50. Pulse rate was not noted. Physical examination of the chest was recorded as "clear." The abdomen was generally tender, but no

TABLE VI

Clinical Cause of Death Compared to Autopsy Findings

Pathological Cause of Death	Principal Clinical Causes of Death												
	Head	Airway	Spinal Cord	Chest	Abdomen	Fractures & Lacerations	Burns	Multiple Injuries	"Shock"	All Others	Agreement	Disagreement	Totals
Head	**221**	—	—	—	—	12	—	—	6	3	221	21	242
Blocked airway	4	**1**	—	5	—	—	—	—	—	1	1	10	11
Spinal cord	—	—	**10**	—	—	—	—	—	—	—	10	—	10
Chest	24	—	—	**62**	3	2	—	—	5	5	62	39	101
Abdomen	21	—	—	6	**56**	1	—	—	9	1	56	38	94
Fractures and lacerations	2	—	—	2	1	**9**	—	—	—	3	9	8	17
Burns	—	—	—	—	—	—	**12**	—	—	—	12	—	12
Multiple injuries	—	—	—	—	—	—	—	**10**	—	—	10	—	10
All other	—	—	—	—	—	—	—	—	—	**19**	19	—	19
Totals											400	116	
Not done	41	—	5	14	10	4	2	8	5	1			90
Totals	313	1	15	89	70	28	14*	18†	25	33			606

* 10 other burn cases were listed under other causes of death although burns were probably the primary cause in all.

† A total of 176 cases (29%) were recorded clinically as having multiple injuries but the cause of death was more specifically listed.

rigidity was felt. An admission diagnosis of "thoraco-abdominal injury" was made. Supine chest and abdominal roentgenograms were made by portable machine and read as "technically poor quality films—recommend re-examination." Hemoglobin was 12.2 and urinalysis was negative. 100 mg. of Demerol was given and intravenous dextrose and water started intravenously. On the following morning, B.P. was 80/50, pulse 120 and Hemoglobin was down to 8.2. No physical findings were noted on the chart. Five hundred cc. of blood were ordered, but before it could be obtained, the patient's blood pressure dropped to 0/0 and he died 10 hours after admission. Post mortem examination showed a left hemothorax (1,000 cc. of blood) and a hemoperitoneum (3,000 cc. of blood), with a ruptured spleen and a lacerated diaphragm. In this case the hemorrhagic shock was neither treated nor recognized.

Case 2. A. H. was a passenger in a car which was involved in a collision. He was not thrown out of the car and was brought to a 100 bed hospital about 11:00 p.m., within 30 minutes of the accident. On arrival he was unconscious and bleeding freely from a scalp laceration. He was described as being "limp and cold" and having "no apparent fractures of the extremities." B.P. was 60/20; pulse 100. X-rays were taken of the skull and reported negative for fracture. No X-rays were taken of the chest or abdomen and no specific physical findings were recorded

TABLE VII

Frequency of Treatments Administered

Total Cases	Clinical Diagnosis	Dextran	Blood	Tracheostomy	Burr Holes	Definitive Surgery	Fixation of Fractures	Cardiac Massage	"Supportive"	No Treatment	Unknown
313	Head injury	36	57	48	89	39	8	4	130	16	10
1	Blocked airway	—	—	1	—	—	—	—	—	—	—
15	Cord injury	—	—	9	—	5	—	—	5	—	1
89	Chest	22	45	38	—	34	14	7	46	7	2
70	Abdomen	28	52	6	—	49	10	12	10	2	6
28	Fractures and lacerations	16	22	2	—	13	26	—	1	—	1
14	Burns	5	12	6	—	—	—	—	2	—	1
18	Multiple injuries	10	11	8	3	4	17	5	3	—	4
25	"Shock"	12	20	3	—	—	—	4	3	—	—
33	All others	6	9	9	—	—	—	—	13	8	3
	Totals	135	228	130	92	144	75	32	213	33	28

TABLE VIII

Evaluation of Cases Receiving "Supportive Treatment" or "No Treatment"

Clinical Diagnosis	Adequate Treatment	Inadequate Treatment	Questionable	Total
Head	91	39	36	146
Cord	3	—	2	5
Chest	15	21	17	53
Abdomen	4	7	1	12
Fractures and lacerations	—	—	1	1
Burns	2	—	—	2
Multiple injuries	2	—	1	3
"Shock"	1	—	2	3
All others	4	8	9	21
Totals	122	75	69	246

for these regions. Intravenous infusion of dextran was begun shortly after admission and the lacerations were carefully washed and sutured. A diagnosis of "head injury and lacerations" was made. He was given sedatives and antibiotics and put to bed. By the following morning the patient was still unconscious but could be partially aroused. His blood pressure had not returned to normal following the 500 cc. of dextran and 1,000 cc. of 5% dextrose in water and therefore 500 cc. of whole blood was given. There was still no appreciable improvement so Levophed was added to the intravenous infusion. This produced a brief blood pressure rise to 110/40, but the man rapidly deteriorated and died eleven hours after admission. Autopsy revealed a hemothorax with fractures of four ribs; hemoperitoneum due to a torn mesentery of the small bowel, but no evidence,

TABLE IX

Over-all Evaluation of Treatment

Clinical Diagnosis	Adequate Treatment	Inadequate Treatment	Questionable	Totals
Head	221	40	52	313
Block airway	1	—	—	1
Cord injury	12	—	3	15
Chest injury	38	26	25	89
Abdominal injury	48	17	5	70
Fractures and lacerations	24	1	3	28
Burns	13	0	1	14
Multiple injuries	15	1	2	18
"Shock"	15	4	6	25
All others	19	8	6	33
Totals	406	97	103	606

either grossly or microscopically, of brain damage. In this case, correct diagnosis was completely overlooked.

Case 3. J. R., a 25 year old soldier, was involved in a car collison within two blocks of a 700 bed teaching hospital. He reached the hospital at 9:00 a.m., within a few minutes of the accident. On arrival, he was semicomatose, but could be aroused. Physical examination of the head and neck, chest, abdomen and pelvis were negative, except for minor abrasions and contusions. Reflexes were described as normal. Neurologic examination was listed as "no abnormal sensory or motor findings." No specific mention is made of eyegrounds on the initial examination. He had an open simple fracture of the left tibia and fibula and an open comminuted fracture of the right patella. B.P. was 90/20 and pulse was 110. A working diagnosis was made of: fractures left tibia and right patella; possible closed head injury. Whole blood was started a few minutes after arrival and a total of 1,000 cc. was given. Blood pressure rose to 110/70 but pulse rate remained over 100 when he was taken to the operating room. There, under general anesthesia, the left leg was debrided and the tibia reduced and fixed with metal screws. The right knee was likewise debrided, portions of the patella removed, the extensor mechanism repaired. Vital signs during the two-hour operative procedure were erratic, but not alarming, and the patient was returned to the recovery ward with a blood pressure of 100/60 and a pulse of 110. In spite of the light anesthetic, he failed to recover consciousness in spite of oxygen, stimulants, and forced ventilation. Hematocrit, blood chemistry studies, ECG, and urinary output were relatively normal. Shortly before death, examination of the eyegrounds revealed severe right papilledema. In addition to the obvious musculo-skeletal defects, autopsy revealed a massive right subdural hematoma. In this case the initial impression of the admitting physician was forgotten in the preoccupation with the less serious but more obvious skeletal injuries.

DISCUSSION

By a conservative estimate it seems apparent that one-sixth of the patients here reported sustained injuries from which recovery would ordinarily be expected under adequate treatment. An additional one-sixth received treatment of such doubtful efficacy that it is reasonable to suppose an appreciable number could have been salvaged. Part of this tragic lack of proper care can be ascribed to faulty diagnosis and the remainder to a failure of the attending surgeons to administer adequate therapy. These therapeutic failures are considered as such only in the light of the diagnostic aids and therapeutic armamentarium normally available in any hospital and neither complicated laboratory tests nor superlative surgical talent were needed to have materially reduced this appalling mortality. Noteworthy in the group of 406 labeled "adequately treated" is the number of head injuries, totaling 221. The majority of these received competent neurosurgical care and only a small proportion had sustained such severe cerebral trauma that recovery was precluded. These data are important not as a criticism of neurosurgeons but to emphasize the great need for improvement in our present methods of caring for head injuries.

Proper transportation, physical facilities, blood, x-rays, and laboratory tests have all been pointed out as important factors in the proper care of the injured (1, 5) but perhaps the weakest link is the doctor himself (3). Certainly doctors must realize that unconsciousness does not always mean head injury, and that surgical skill is of little avail unless the correct diagnosis is reached by careful examination. The proper care of the injured patient involves knowledge of all branches of surgery and much of internal medicine, and complacency with present methods must never blind the surgeon to the vast areas of improvement needed in the care of the trauma.

SUMMARY

1. A brief analysis has been made of the records of 606 healthy adult males who were injured and who died in a hospital within 2 weeks of their admission.
2. Three hundred and seventy six were injured in moving vehicle accidents.
3. At least one out of six (96 cases) would have had an excellent chance of survival had prompt diagnosis been made and adequate treatment instituted.
4. An additional one-sixth of the cases, 103, had such limited treatment that an appreciable number could probably have been salvaged.
5. Over one-half of the acceptably treated cases were uncomplicated head injuries, pointing up the necessity for improvement in the present methods of treatment of head trauma.
6. Physicians must be better trained in the surgery of trauma if such needless loss of life is to be avoided.

REFERENCES

1. Bowers, W. F. *Surgery of Trauma*. J. B. Lippincott Co., Philadelphia, 1953.
2. Curry, C. J. and Lyttle, S. N. The speeding ambulance. Am. J. Surg., **95:** 507–508, 1958.

3. Johnston, C. G. Teaching of trauma in medical schools. Am. J. Surg., **98:** 566–568, 1959.
4. Kulowski, J. *Crash Injuries.* Charles C Thomas, Springfield, 1960.
5. McLaughlin, H. L. *Trauma.* W. B. Saunders Co., Philadelphia, London, 1959.
6. National Safety Council. Accident Facts. 1958, 1959.

DISCUSSION

Dr. Donald M. Glover (Cleveland, Ohio): I would like to comment briefly on Dr. Van Wagoner's interesting and impressive figures, which emphasize the obvious: that our initial evaluation of injury may be quite inadequate. Recognizing that many of his patients were treated where conditions were relatively ideal, one can but wonder how much worse may be the figures that come from inadequately staffed emergency facilities in hospitals all over the country.

Dr. Joseph R. Shaeffer (San Antonio, Texas): Dr. Van Wagoner's paper speaks for itself. His statistical analysis is very impressive. The facts revealed should be shocking. Lives lost through faulty diagnosis and mismanagement—lives which probably could have been saved—is an appalling revelation. Dr. Marble asked me a moment ago if the Armed Forces still permitted the 3-day pass. I am sure he had in mind the tendency to use the pass to speed to and from unreasonably remote places. No doubt this is related to the high incidence of vehicular accidents among Armed Forces personnel. I prepared a paper for Dr. Curry on this subject some time ago for publication in a special issue of the American Journal of Surgery. Dr. Van Wagoner's figures are even more impressive.

A STATISTICAL STUDY OF 1000 BURN PATIENTS ADMITTED TO THE PLASTIC SURGERY SERVICE OF THE UNIVERSITY OF TEXAS MEDICAL BRANCH, 1950–59

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During the past nine years, since clinical experimentation with exposure therapy of burns was initiated on the Plastic Surgery Service at the University of Texas Medical Branch, over 1300 burned patients have been admitted for primary therapy. In an early paper ("An Approach to the Problem of Burn Sepsis with the Use of Open-Air Therapy," Ann. Surg. **134:** 474, 1951) a group of 104 consecutive patients treated by exposure during a 7 months period were compared with a similar number (103) treated by conventional occlusive dressings during the preceding 7 months. Exposure was found to have advantages with particular reference to length of hospitalization; duration of pyrexia; and skin grafting, blood transfusion, and sedation requirements.

The study was undertaken principally to evaluate the feasibility of employing this technique in disaster situations, and conclusions were drawn as follows: that the exposure method was applicable to nearly all types of acute burns but to flash burns in particular; that it could be employed during the emergency period by both first-aid workers and professional personnel; that it required a minimum amount of man-hours of work on local wound care in the early stages; that it was inexpensive and did not require large reserves of dressings; that it did not predetermine subsequent treatment; and that it provided relief from pain associated with repeated dressings. In considering ordinary civilian use of exposure, certain disadvantages were pointed out, which have since been reemphasized many times. The most important of these were considered to be the inherent time limitation and management of the circumferential lesions. Although the mortality rate was not affected by alterations in local therapy, the period of morbidity was considerably lessened in those cases where adequate exposure could be obtained.

Even at the time of the initial report, it was our practice to place burned hands in dressings for a period of 48 hours in order to achieve immobilization in the position of function. We soon came to treat hands by the closed method during the entire pre-grafting phase and have become gradually much less standardized in our handling of other difficult areas so that our present philosophy is to look upon exposure and dressings as complementary rather than antagonistic techniques. This view is shared by the majority of large burn centers, and it is, therefore, not possible to make the same comparisons as formerly.

Read before the Twentieth Annual Session of The American Association for the Surgery of Trauma, Coronado, California, October 5–7, 1960.

The present review of 1000 hospitalized burn patients has been undertaken to collect data on the types of patients admitted to our service in a state teaching hospital and to focus attention on those factors which influence length of hospitalization and total healing time without analyzing in detail the regimen of therapy. For this purpose cases have been selected at random excluding those admitted for definitive surgery.

ETIOLOGY

Flash and flame burns have accounted for 77.1% of the cases in the series under review (Table I). The importance of the open gas heater as an etiologic agent for burns in our section of the country may be inferred from the fact that two-thirds of all burns have been admitted during the fall and winter months (October to March). Since cold weather occurs only sporadically, central heating units are uncommon, particularly in houses of the lower income groups, and both children and adults are subject to severe burns from close contact to the open flames of stoves used for heating purposes or for cooking, including backyard barbecue pits. Numerous burns have also resulted from pouring gasoline or kerosene on wood or charcoal, from automobile accidents, and from careless use of other inflammables in the home or in industry. An occasional patient has been injured in bonfires or from use of a flame thrower on ranches in the destruction of thorns on cactus plants in their preparation as food for cattle.

Thirteen per cent of the burns have been produced by hot water and other fluids, notably coffee, tea, cereals, and grease. Bathtub accidents have occurred following epileptic seizures and as the result of neglect to test the temperature of water prior to immersion of small children or lack of proper supervision while they are taking a bath by themselves.

Contact burns have been found in 5.1% of patients. In nearly every instance only the hands and arms and the head and neck have been involved. Hot tar used in roofing and in road-building has been responsible for particularly deep severe burns because of the temperature involved. Other industrial burns have been received by contact with hot sulfur during one phase of the mining process and from metal pipes with inadequate insulation. The majority of contact burns in the home are from stoves and hot irons.

Electrical burns, which constitute 3% of the group, have been limited in our experience to infants chewing the wires of household appliances or putting their fingers into empty sockets or to adult males working near high tension wires. Chemical burns in 1.4% of patients have resulted from a variety of agents, the most common being battery acid, sulfuric acid, lye, and unignited gasoline. Surprisingly enough, only 4 patients were hospitalized because of severe sunburn, although Galveston is a summer resort, and many persons are treated in the Emergency Room of the Hospital as out-patients.

AGE, SEX, AND RACE

Only a small number of burns have occurred in infants under one year of age (2%); nevertheless, 20% of the entire group have been in children 5 years of age

TABLE I

Cause of Burn

	Number	Percentage
Flash and flame	771	77.1
Hot fluids	130	13.0
Contact	51	5.1
Electrical	30	3.0
Chemical	14	1.4
Sunburn	4	0.4
Total	1000	

TABLE II

Age Distribution in Burns

	Number	Percentage
0–1	21	2.1
1–5	179	17.9
5–10	161	16.1
10–20	141	14.1
20–30	145	14.5
30–40	109	10.9
40–50	89	8.9
50–60	67	6.7
60–70	38	3.8
70–80	36	3.6
80–90	14	1.4
Total	1000	

and younger and 36% in 10 and under. Fourteen per cent are seen in the decade from 10 to 20 and again from 20 to 30, after which the incidence begins to decline (see Table II). It is fortunate that only 8.8% of burns have been received by individuals over 60 years of age since the prognosis is so poor in elderly persons, even with burns of less than 30% of the body surface.

An analysis of burns by sex indicates that distribution has been fairly even, with males 52.4% and females 47.6%. Approximately 25% of the patients admitted for treatment of burns have been Negroes. This is approximately twice as great as the Negro population in the state of Texas (12.7%) and is due to the high incidence of indigent patients in this race group who are referred from distant areas to the Medical Branch Hospitals in Galveston.

LOCATION AND EXTENT OF BURN

Approximately half (52%) of patients reviewed in our series have had burns of 20% or less of the body surface (see Table III). An additional 20% fall within the range of 20–30% involvement, and 11% in the 30–40% group. The number of

TABLE III

Extent of Body Surface Involvement in Burns

% Burn	Number of Patients	Percentage
<10	252	25.2
10–20	264	26.4
20–30	201	20.1
30–40	110	11.0
40–50	62	6.2
50–60	51	5.1
60–70	22	2.2
70–80	19	1.9
80–90	19	1.9
Total..........................	1000	

persons with burns of more than 50% who are referred to our service is constantly increasing as the standards for treatment of burn shock have improved in small communities throughout the state and more patients with irreversible critical burns survive the early period. They comprise only 11% of the entire group but account for 60% of the deaths.

The location of burns depends in large measure on the circumstances of injury. In the entire series, however, the head and neck region was involved far less than other areas of the body (32.4% of patients), and the upper and lower extremities were affected more often than the trunk. In burns of minor extent (below 20%) approximately half of the cases had localized lesions confined to the upper or to the lower extremities only.

Excluding deaths, there have been a total of 872 admissions. Of these 246, or 28%, have had second degree lesions with distribution even up through the 60–70% category. The remainder have had third degree burns or various combinations of partial and full thickness skin loss.

In the group of patients who required no skin grafting procedures, *i.e.* those burned by hot liquids, hot objects, and minor flash burns, the majority of first and second degree lesions (76.7%) involved less than 20% of the body surface, while the remainder were chiefly in the 20–50% group (23.5%). On the other hand, the number of patients with third degree lesions were nearly evenly divided (51% and 49%) between burns of minor and major extent, since in these instances the source of injury was more likely to be flames which caught clothing and spread widely after initial contact.

ADMISSION FACTORS

Approximately one-third of patients were admitted to our institution within 48 hours post-burn; three-fourths were referred during the first month. Of the one-fourth who came in after this period, many had had unsuccessful skin grafting procedures or presented special problems of therapy, *e.g.* involvement of the face and genitalia or local infection of the burn site. In order to assess the importance of early admisson and adequate fluid therapy, as related to total hospital time and other factors, the patients who survived were divided into two groups: those admitted within the first 2 days, 33%, (see Table IV), and those who came after that time, 67%, (see Table V). Practically all of the referrals in the second group were from distant areas; the acute burns, however, were from both local and distant sections of the state.

The average time for admission in the delayed group of individuals with first and second degree burns up to 50% involvement of the body surface was the 38th day after injury, and the total time required for healing was 57 days as compared with 18 days for a similar group admitted to our service within 48 hours. This is ample evidence that partial thickness burns require careful management. It is interesting to note that the average period of hospitalization on our service for the subacute or chronic burns, 20 days, is approximately the same as for acute burns directly admitted, 17 days, regardless of the length of prior treatment elsewhere.

If the total healing times are examined separately (see Table VI), it will be noted that the acute burns of minor extent (less than 20%) required an average time of 12 days, whereas the late group required a total of 66 days. In the 20–50% category the figures show 22 days as compared with 50; here, however, referral was made considerably earlier than in the first group.

In contrast to the ungrafted burns, patients with third degree lesions hospitalized during the first 48 hours (137) were outnumbered by those sent in later (489). For the most part these represented cases which had been well managed during the early period but were referred for skin grafting procedures. Some had had complications of one type or another. There was a large enough number of cases in the less than 20% groups for conclusions to be drawn with respect to average time between injury and first grafting procedures, average hospital stay on our service and average time between burn and discharge (see Table VII).

When seen within the first 48 hours the 62 patients with less than 20% involvement were grafted for the first time on the 24th post-burn day. In nearly every instance lesions of less than 10% could be covered in one procedure, whereas those in the 10–20% category required two or even three grafts in nearly half of the cases. The average hospital stay in this early group was 45 days and did not vary significantly according to the extent of burn. The average time of admission of patients with third degree burns referred after the initial 48 hours was the 37th day. In general, 8 days were required for systemic and local therapy in preparation for the first grafting procedure on the 45th day. A patient burned to the same extent and admitted early would ordinarily be ready for discharge at this time (see Table IV, above). In general, more patients admitted after 48 hours required grafting than in the early group probably because of bacterial contamination and conversion of small deep second degree areas to full thickness skin loss. The average total healing period was 26 days longer than in the patients admitted as acute burns; 21 days of this time was between injury and the first graft and 5 days between the first graft and hospital discharge. Although

TABLE IV

Burn Survivals—Admissions Within the First 48 Hours Post Burn

	Per Cent Burn								
	0–10	10–20	20–30	30–40	40–50	50–60	60–70	70–80	80–90
Pts. not grafted (173)									
Distribution	65	67	23	13	3	1	1	0	0
Average time from burn until discharge (days)	11	13	21	24	19	58	36	0	0
Average hospital stay (days)	11	11	21	24	19	58	36	0	0
Pts. grafted (137)									
Distribution	18	44	30	24	14	5	1	0	1
Average time from burn until discharge (days)	44	47	62	58	72	101	68	0	123
Average hospital stay (days)	44	45	62	58	72	100	68	0	123
Average time from burn to first graft (days)	24	24	24	25	28	28	31	0	14

TABLE V

Burn Survivals—Admission After the First 48 Hours Post Burn

	Per Cent Burn								
	0–10	10–20	20–30	30–40	40–50	50–60	60–70	70–80	80–90
Pts. not grafted (73)									
Distribution	37	17	15	2	2	0	0	0	0
Average time from burn until discharge (days)	36	96	75	34	42	0	0	0	0
Average hospital stay (days)	16	18	27	27	13	0	0	0	0
Pts. grafted (489)									
Distribution	128	132	125	52	31	17	3	0	1
Average time from burn until discharge (days)	73	70	112	103	131	127	216	0	392
Average time from burn to first graft (days)	50	39	68	51	38	52	42	0	42
Average hospital stay (days)	32	37	56	66	99	108	191	0	381

the average hospital time was 8 days shorter on our service, this figure does not include the length of treatment in other institutions; it does mean, however, that a burn "ready" for grafting can be prepared in about a week's time, whereas an acute burn, no matter how well treated, will ordinarily require approximately 3 weeks treatment prior to coverage. If there were some reliable means of decreas-

TABLE VI

Comparison Data on Admissions—Patients with First and Second Degree Burns

	0–20%	20–50%	50–90%
Admissions less than 48 hours post burn			
Average time between burn and admission date (days)	<1	<1	<1
Average hospital time (days)	11	21	47
Average total healing time (days)	12	22	48
Admissions over 48 hours post burn			
Average time between burn and admission date (days)	49	28	0
Average hospital time (days)	17	22	0
Average total healing time (days)	66	50	0

TABLE VII

Comparison Data on Admissions—Patients With Third Degree Burns

	0–20%	20–50%	50–90%
Admissions less than 48 hours post burn			
Average time between burn and admission date (days)	<1	<1	<1
Average time between burn and first graft (days)	24	25	21
Average hospital stay (days)	45	64	97
Average time between burn and discharge (days)	46	65	98
Admissions over 48 hours post burn			
Average time between burn and admission date (days)	37	42	18
Average time between burn and first graft (days)	45	52	45
Average hospital stay (days)	35	73	99
Average time between burn and discharge (days)	72	115	124

ing the eschar period other than early massive excision, which we feel is applicable in selected cases only, the healing period might be shortened.

In the patients with 20–50% burns, the group of 68 with full-thickness lesions who were admitted early were usually ready for grafting on the 25th day at about the same time as those in the less than 20% category. It is evident that the total area of a third degree burn does not significantly affect the time required for sloughing of the eschar and formation of granulation tissue. In most instances more than one graft was required, and the total length of hospital stay from the time of application of the first procedure was correspondingly increased—to 40

TABLE VIII

Burn Deaths, According to Age

Age	Number of Deaths	Percentage of Deaths
<1	1	4.7
1-5	12	6.7
5-10	22	13.6
10-20	11	7.8
20-30	24	16.5
30-40	13	11.9
40-50	9	10.1
50-60	13	19.4
60-70	9	23.7
70-80	10	27.7
80-90	4	28.6

TABLE IX

Burn Deaths, According to Extent of Involvement

% Burn	Number of Patients	Number of Deaths	Percentage
<10	252	4	1.6
10-20	264	4	1.5
20-30	201	8	4.0
30-40	110	19	17.3
40-50	62	12	19.3
50-60	51	28	54.9
60-70	22	17	77.2
70-80	19	19	100.0
80-90	19	17	89.5
Total....................	1000	128	12.8

days, as compared with 22 days in the less than 20% burns. The necessity for multiple grafting is dependent upon other factors in addition to the extent of skin loss, *e.g.* location of lesions in areas which cannot be managed conveniently following simultaneous grafting, the patient's general condition, the availability of donor skin in suitable areas, etc. The total healing time of 65 days, average, differs from the less than 20% group by only 19 days, the extra time which elapsed between the first graft and the hospital discharge date. The average date of admission for the 208 burns seen after the initial 48 hours was the 42nd day. An average of 10 days was required for preparation, and the total healing time was 50 days more than for burns admitted early. The total hospital stay at our institution was 9 days longer than for those seen in the acute stage, besides prior treatment, and there were corresponding increases in the time from the injury to the first graft (an additional 27 days) and in the period from first grafting to date of discharge (an additional 23 days).

There were only 7 surviving patients with burns of more than 50% of the body

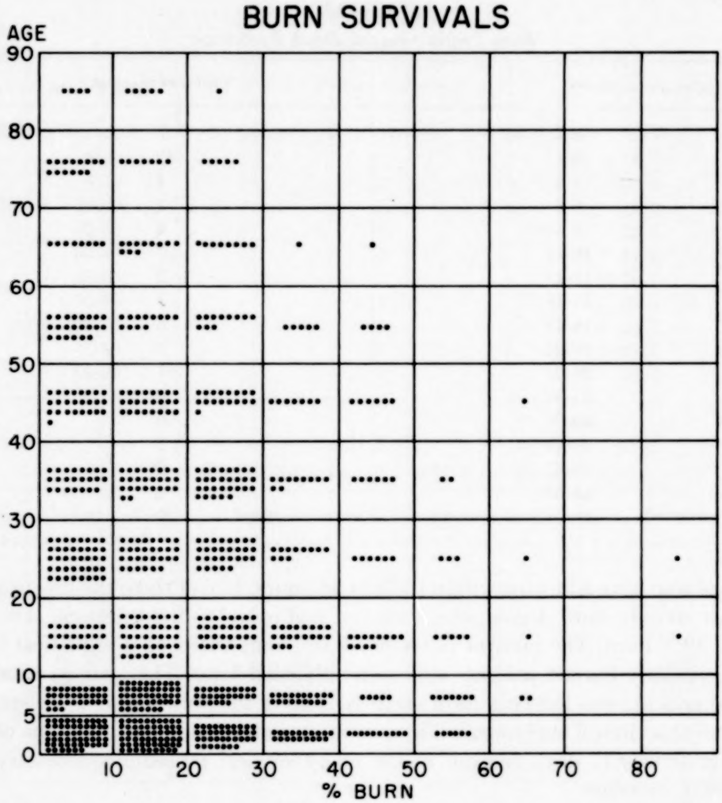
TABLE X

Burn Deaths—Day of Death Post Burn

Day	Number of Patients
0–2	5
2–4	12
4–6	4
6–8	9
8–10	6
10–12	7
12–14	2
14–16	8
16–18	6
18–20	5
20–25	11
25–30	9
30–35	9
35–40	7
40–45	3
45–50	2
50–over	23

surface who were admitted within the first 48 hours. In 6 of these the lesions were almost entirely third degree; one, however, had only 7% full-thickness skin loss in an 89% burn. The number is too small for comparison on a statistical basis with similarly burned patients who were admitted later. The average time for initial grafting was less because of early excision of the burn eschar in several instances as a clinical experiment. The average hospital period from the time of the first graft was 77 days because of the many surgical procedures necessary for complete coverage.

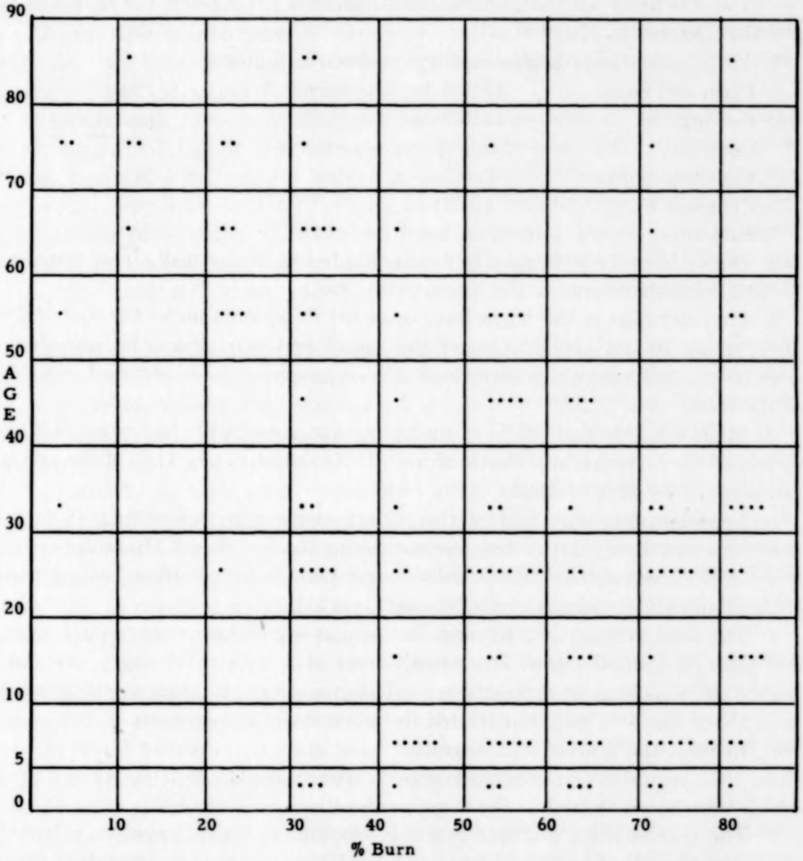
A total of 21 patients in the 50–90% group were admitted to our service after the acute period. The average time was the 18th day post-burn, much earlier than in the case of the less severely injured patients. Most of the survivors (78%) had lesions of 50–60% of the body surface. These showed only a relatively small difference in total healing time (26 days) over those with less extensive burns. Late admissions required 24 additional days prior to the first graft, but only 2 extra days from this time to the date of discharge. In these critically burned patients numerous variabilities arose in individual cases—problems related to prolonged bedrest and immobilization, *e.g.* renal calculi, decubitus ulcers, joint changes, etc., as well as to complications of the burns *per se*—so that the effect of later admission became less important than in the groups previously discussed. The most severe burn which survived was in a 20-year-old colored female (85% with 78% third degree involvement) who was admitted on the 11th day after injury. She was kept in the hospital for 381 days, at which time her family took her home without permission. Meanwhile she had required amputation of both legs at the mid-femur region and of one arm in the mid-humerus region and had had a total of 22 skin grafting procedures, including both homografts and autografts, for



complete coverage. She ultimately died at home 9 months after discharge, of a fulminating urinary tract infection.

BURN DEATHS

There were 128 deaths in the group of 1,000 patients. The ratio of white (92) and colored (36) patients was essentially the same as in the total admission figures. There were, however, more female than male deaths, 76 as compared with 52. The age at the time of death varied from seven months to eighty-nine years (see Table VIII), and in general, the percentage of deaths was lowest in children under five years. It was stable between five and fifty years, after which there began a distinct rise in mortality, and many individuals over fifty died of burns of less than 30%. In fact, only two over sixty survived burns of more than this extent. Below 30% involvement of the body surface, the mortality rates were low, particularly in persons under 50 years of age, and this is the critical level, regardless of the time of admission (see Tables IX and X and Fig. 1).


BURN DEATHS

Approximately one-fourth of the 128 deaths occurred in the first week, and 17 of these (13.3% of the total) were during the first 4 days. Some of those in this group had sustained massive third-degree burns and, despite vigorous supportive therapy, did not recover from the initial shock. Others were transported for considerable distances to our hospital with inadequate immediate treatment and no intravenous fluids en route. Deaths after the early period were evenly distributed over the next 5 weeks, but only 28 (21% of the total) occurred after the 40th post-burn day.

SUMMARY AND DISCUSSION

At the University of Texas Medical Branch 1000 cases have been selected from a nine-year period for statistical study. Data have been collected with regard to etiology, sex, race, age, location and extent of body surface involvement, depth of burn, and factors affecting healing time. These may be summarized as follows:

1. Two-thirds of all burns have been admitted during the fall and winter months (October to March)

2. Distribution according to etiology has been as follows:

Flash and flame	77.1%
Hot liquids	13.0%
Contact	5.1%
Electrical burns	3.0%
Chemical burns	1.4%
Sunburn	.4%

3. Burns have been fairly evenly distributed between males and females; 25% of lesions have occurred in Negro patients.

4. Fifty per cent of the burns have occurred in patients under the age of 20; 36%, under 10 but only 2% under the age of one year. Burns in individuals over 60 years of age, which carry such a poor prognosis, have occurred in 8.8% of the cases.

5. Approximately half (52%) of the patients reviewed have had burns of 20% or less of the body surface. Burns of over 50% comprise only 11% of the group but account for 60% of deaths.

6. Approximately one-third of the patients were admitted within 48 hours post-burn and three-fourths were referred during the first month. In both partial- and full-thickness lesions substantially longer periods for complete healing were required in patients admitted after the early period.

7. The total healing time for first and second-degree burns was considerably less than for grafted burns. Even small areas of 5–10% third degree required nearly twice as long as extensive second degree areas. In general, the healing time above the 20% level was related to the extent of involvement.

8. In both the grafted and ungrafted groups minor extremity burns of less than 10% required longer healing periods than those of 10–20% surface area which were not restricted to the lower extremities.

9. The necessity for multiple grafting procedures, which increases substantially the periods of hospitalization and total healing time, is dependent upon several factors other than the size of the area of skin loss, *e.g.* the location, the patient's general condition, the availability of donor skin, etc.

10. The overall mortality rate in the series of 1000 burn patients was 12.8%. Below 30% involvement of the body surface, the mortality rates were low, particularly in persons under 50 years of age, and this was the critical level, regardless of the time of admission. Seventy-nine per cent of deaths occurred in the first 6 weeks; 24%, during the first week post burn.

Our teaching institution is not situated in an industrial or urban area *per se* but draws patients from a wide radius. It is obvious from our statistics that the seasonal incidence of burns in a predominantly low income group is related to the use of inadequately protected open fires employed for heating. Fifty per cent occurred in young people of less than 20 years of age. The fact that the majority of cases were due to flash and flame suggests another preventable factor: namely, the inflammability of night wear and other clothing. The reduction of domestic fires is a serious international problem from the standpoint of world health, and although progress is being made in this direction, much yet remains to be done by flame-proofing of textiles, changes in design of stoves, use of non-explosive fuels, education of the general public, etc.

Although under disaster conditions triage of the patients in our series might have categorized half in the self-care group in the early stages by reason of having burns of less than 20% extent of body surface, it is obvious that those with small deep lesions actually require longer for healing than extensive superficial burns. Also, patients with small lower extremity lesions have a longer period of morbidity than those with burns of greater extent which involve primarily the trunk and upper extremity, excluding, of course, the severely burned hand.

Our over-all mortality of 12.8% for the nine-year period does not include out-patient burns, which would necessarily lower the figure considerably. There has been, however, among the hospitalized group a steadily rising incidence of deaths as a reflection of the admission of more severely burned patients. It is evident that more and more cases with burns of minor and moderate extent are being cared for in their own communities unless complications develop during the pre-grafting and grafting stages. More poor-risk cases are referred early, and a significant number of these are handicapped by age, pre-existing disease entities and obesity. In a recent study on our service (1959) it was noted that 22% of the deaths occurred among patients over 60, and 43% among obese patients, particularly females. Sixty-two per cent of obese burned patients died and 55% of patients over 60, irrespective of the extent of their lesions. The muscular adult male appears to carry an unfavorable prognosis as well, and we have been interested in studying the factor of body habitus on the reaction to thermal trauma, other factors being equal. The thin boy of eight to eleven years of age appears to have the best prognosis in a burn of moderate extent.

Only 13% of deaths have occurred during the first week post-burn, with 3% during the first 48 hours. In 1959–60 on our service there was a total mortality rate of 23% but only 2 of the 39 deaths occurred within the first 48 hours. In this country in 1943, according to the National Research Council Manual on *Burns, Shock, Wound Healing, and Vascular Injuries* published by the Armed Services, between 50 and 75% of burn deaths were the result of "shock." It is generally assumed that the improvement in the early mortality rate is related to more adequate fluid therapy, particularly of colloids. With the recent relaxation of strict fluid formula requirements, however, in most teaching centers and the tendency to gauge the efficacy of resuscitative fluids on the hourly urinary output, it is interesting to speculate as to whether other factors may be responsible for the improvement in the early response. Inasmuch as our entire bacterial flora have changed during the past 20 years as a result of wide-spread antibiotic therapy, the possibility exists that at one time more virulent strains of certain organisms may have contributed to early death in burn shock. Certainly the pseudomonas problem did not exist at that time, as now, as the cause of sudden and overwhelming septicemia at a later stage.

Although interpretation of statistics is fraught with many pitfalls and data collected over a long period of time do not necessarily reflect the *status quo*, we have found it true in our year-to-year analysis of burn patients that both partial-thickness and full-thickness lesions have healed in a shorter period of time in patients admitted early to a burn center for primary care, irrespective of the initial method of local management. This we believe is due to the team approach and to the emphasis on mechanical cleansing procedures during the post-eschar phase in units where it has been imperative to develop efficient organization for burn care in order to handle the patient load with the personnel available and to provide for as early rehabilitation as possible.

DISCUSSION

Dr. Curtis P. Artz (Jackson, Mississippi): My compliments and congratulations to Dr. Blocker for such a tremendous experience and such fine results. It is an opportunity that is afforded few men in a lifetime, to be able to assemble such a fine team of people and carry out so thorough a study in 1000 burned patients.

It shows the advantage of studying burns, when you see that he has 40 and 50 per cent burns out of the hospital in 72 days, 50 to 60 per cent burns out in 101 days. This is done by expert knowledge of the burn wound, and sheer hard work.

He emphasized the point of early grafting, and although the late Dr. Harvey Allen, whose teaching we all cherish so much, championed early grafting, it is sometimes difficult to apply that first graft on the twelfth or fourteenth day, as is so frequently emphasized. Dr. Blocker's average day of grafting was 24 to 31, and this is pretty accurate, unless one is treating only small burns where early surgical excision is warranted. If one waits until some of that eschar begins to slough, as is necessary in large burns so that excessive stress is not added by anesthesia and excision, then it will be about 24 to 28 days before a graft can be applied.

I think that a formula is valuable. I doubt how well we follow it, but it does serve as a guide. Likewise in grafting, I think we have to set up for ourselves deadlines. Man has a tendency on the burned patient to say, "Well, it won't hurt to let him go two more days." Then he is cancelled on the schedule, and "It won't hurt to go three more days."

One should set a deadline that the first graft be applied by the 26th day and thereafter a graft at least once a week. Every time the patient is put to sleep there is an opportunity to take some skin with the electric dermatome and obtain additional wound coverage. An important aspect of burn therapy is the rapidity with which the wound is covered, because it is the wound that is responsible for systemic changes and the more rapidly it is closed the better.

I should like to ask Dr. Blocker why he feels that his mortality in the 40 to 50 per cent burn was so low—19 per cent—when the mortality in the 50 to 60 per cent group is 54 per cent.

Dr. Truman G. Blocker, Jr. (Closing) (Galveston, Texas): I would like to thank the discussers, and agree that each of the burn patients must be individualized.

One of the important points, I think, in the study that we made was with regard to the time of debridement and grafting. We had been going around talking glibly about debridement on our patients on the 14th to 16th day and grafting on the 18th day as a general rule; this did not turn out to be quite true. When we reviewed our cases we found that the average time was around 21 days for debridement and 24 days for grafting. In the patients who came to us from other areas after 48 hours, from 48 hours to as much as a month, we found that approximately four to ten days of preparation were required for grafting.

I think the difference between the 40 per cent burn with 19 per cent mortality and the 50 per cent burn with 54 per cent mortality is that in the latter group there was predominance of obese females with leg burns as well as a large number of respiratory burns, as well as a larger area of surface involvement. Obesity, face burns with their associated respiratory difficulties in some instances, and also the severe leg burns associated with the large area burns, kept the patient immobilized for a long period of time and contributed to increased mortality rates.

Other factors are age, and in the older people the concurrent diseases which are present. Also in some patients there is evidently just plain "bad" protoplasm. It's much easier to say you can't make a silk purse out of a sow's ear unless you have a silk sow.

ARTERIAL INJURIES IN CIVILIAN PRACTICE: A CURRENT REAPPRAISAL WITH ANALYSIS OF FORTY-THREE CASES

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The management of acute arterial injuries has been radically altered since World War II. Direct arterial reconstruction has been shown to be almost routinely successful. When early in the Korean War the same techniques used in World War II were employed, the amputation rates were essentially the same as those in the former conflict. After the adoption of direct reconstructive techniques (13, 25), however, the over-all amputation rates dropped from approximately 50 per cent to about 13 per cent, as reported by Hughes (10). This author found that primary anastomosis with the patient's own arterial tissue provided the best results, with autogenous vein grafts and homografts being next most useful in that order. Yet it was not possible to determine from the above reports the extent to which their cases were selected. Bradford (2), who studied the patients admitted to an advanced field hospital in World War II, emphasized the difficulties involved in securing prompt treatment of arterial injuries under those conditions. Thus the cases which do reach a military hospital may represent a select group.

The purpose of this paper is to review all the cases of arterial injury treated at the Hospital of the University of Mississippi since its opening July 1, 1955 to September 1, 1960. This series reflects the changes in the management of arterial injuries which resulted from the general preoccupation with vascular surgery which followed World War II. Previous reports in the literature and our own experience emphasize the desirability of early repair.

MATERIAL

Our series consists of 43 cases (Table I) which have been divided according to the following classification:

1. Complete division
2. Incomplete division
    a. Arteriovenous fistula
    b. False aneurysm (pulsating hematoma)
    c. Simple blood loss
3. Puncture wounds
4. Contusions
5. Arteriospasm and kinking (including compression)

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COMPLETE DIVISION

There were nine cases of complete division (Table I-A). The injuries in these cases were caused by sharp instruments or gunshot. In six cases the artery involved was a minor one and was simply ligated; however, most of these arteries would now be repaired under current policy. The results with reconstruction were good with the exception of one case of severe associated bony and soft tissue injury involving the humerus and shoulder. This extremity was amputated with no attempt being made at reconstruction.

Illustrative case: E. M., a 21-year-old Negro male, was admitted to the University Hospital with a stab wound from a butcher knife. Physical examination revealed a 5 cm. transverse laceration on the anterio-medial aspect of the right lower thigh. Through this wound were protruding two hemostats beyond which no pulses were present (Fig. 1). These instruments had been applied by the patient's physician in his office under the most harrowing of circumstances. The patient was taken to the operating room immediately, and the area was explored. The femoral artery, vein and nerve were found to have been severed. The vein was ligated, and the artery was repaired using a continuous suture of 4-0 arterial silk. The patient was discharged on the thirteenth hospital day with a good dorsalis pedis pulse. Follow-up visits have continued to demonstrate good pulses.

The femoral nerve injury at this low level produced no significant neural deficit. The vein would now be repaired rather than simply ligated.

INCOMPLETE DIVISION

In the incomplete division group there were 13 arteriovenous fistulas, 8 false aneurysms and 5 cases which were operated upon before there had been time for the development of aneurysms or arteriovenous fistulas.

Arteriovenous Fistulas (8, 9, 11, 12, 21, 24). Direct reconstructive techniques were used in most cases of arteriovenous fistulas involving large arteries (Table I-B). One patient, W. L., had a quadruple ligation of the popliteal arteriovenous fistula in 1955 before direct repair had become our routine practice. A quadruple ligation was performed on patient A. M. due to her serious congestive heart failure. The late results have been good in all cases in which follow-up has been achieved.

Illustrative case: M. C., a 34-year-old white male, accidentally shot himself in the upper third of the right thigh with a .38 caliber pistol 18 hours prior to admission to the University Hospital. Dorsalis pedis pulses were palpable bilaterally. A bruit and accompanying thrill were identified in the region of the wound. At operation a large fistula between the femoral artery and vein was found (Fig. 2). The vein was ligated; 1 inch of artery was excised and an end-to-end anastomosis was performed. Pulses were immediately restored distal to the site of repair.

False Aneurysms (*Pulsating Hematomas*) (Table I-B). The results in the eight cases of false aneurysms were uniformly good. These cases were treated either by ligation of the injured artery where the vessel was unimportant or by reconstructive techniques.

Illustrative case: E. S., a 30-year-old Negro female, was admitted to the

TABLE I

Cases of Arterial Injuries, July 1, 1955 through September 1, 1960

Initial	Age	Sex	Injury	Interval Since Injury	Pathology	Operative Procedure	Result
					A. Complete Division		
SB	4	F	Lacerations of arteries in lower arm by broken milk bottle	6 hrs.	Severance of median and musculotaneous nerves and brachial artery	End-to-end anastomosis	Good
EDP	25	F	Stab wound of right chest	12 hrs.	Laceration of intercostal and internal mammary	Ligation	Good
JB	8	M	Laceration of lower leg	4 hrs.	Severance of anterior tibial artery	Ligation	Good
EM	21	M	Stab wound of thigh	5 hrs.	Severance of femoral artery and vein	End-to-end anastomosis; vein ligation	Good
TH	26	M	Crushing injury to left upper arm	26 hrs.	Complete avulsion of axillary artery, fracture of humerus, extensive soft tissue injury	Amputation	Amputation
VG	32	F	Laceration of wrist by broken glass	1 day	Complete severance of ulnar artery	Ligation	Good
JM	31	M	Laceration of wrist by glass door	3 hrs.	Severance of ulnar artery, nerve, and palmaris longus and other tendons; partial severance of profunda and sublimis tendons	Ligation	Good
BJJ	16	F	Fell through glass door	6 hrs.	Severance of ulnar artery, tendons and nerves	Ligation	Good
JR	18	M	Bullet wound of popliteal fossa	5 hrs.	Severance of popliteal artery	End-to-end anastomosis	Good

B. Incomplete Division (A–V Fistulas)

GW	53	M	Stab wound of lower left ear entering oropharynx	11 days	Facial a-v fistula	Quadruple ligation	No complications
FC	22	M	Bullet wound of left groin		Femoral a-v fistula	Primary anastomosis; veins ligated	Good dorsalis pedis pulse
WRC	19	M	Shotgun wound of right arm and both legs	2 mos.	Lower brachial a-v fistula and minor a-v fistula in popliteal space; causalgia of arm and leg	Primary closure brachial artery and vein defect; quadruple ligation of popliteal a-v fistula	Excellent
AH	48	F	Aorta injured at lumbar laminectomy	8 yrs.	Abdominalaortic a-v fistula	None	Poor
CP	9	M	Shotgun blast to body and right leg	3 mos.	Posterior tibial a-v fistula; causalgia	Quadruple ligation of posterior tibial a-v fistula	Good dorsalis pedis and posterior tibial pulses
JTP	30	M	Shotgun wound of right thigh	13 yrs.	Multiple a-v fistula of muscle branch of femoral artery	Excision; quadruple ligation	Good
EW	18	M	Stab wound in right side of neck with screwdriver	3 mos.	Right common carotid a-v fistula	Bypass around fistula; fistula excised; vein ligated; artery reanastomosed.	Good
AM	34	F	Stab wound of left supraclavicular area	15 yrs.	Subclavian a-v fistula; false aneurysms	Quadruple ligation	Good
ID	16	F	Foreign body in leg	7 yrs.	Congenital a-v fistula of arteries of foot	Excision	Good
WL	52	M	Shotgun wound of right popliteal region	3 mos.	Popliteal a-v fistula	Quadruple ligation; excision and anastomosis	No follow-up
MC	34	M	Bullet wound of thigh	24 hrs.	Femoral a-v fistula	Vein ligated; end-to-end anastomosis	No follow-up
RC	14	M	Bullet wound of thigh	60 hrs.	Femoral a-v fistula	End-to-end repair of artery; vein ligated	Good
ET	56	M	Unknown	Unknown	Axillary a-v fistula	Lateral repair; veins ligated	Good

TABLE I (*cont'd*)

Initial	Age	Sex	Injury	Interval Since Injury	Pathology	Operative Procedure	Result
					B. Incomplete Division (False Aneurysms and Pulsating Hematomas)		
JH	38	M	Bullet wound of thigh	3 wks. and 8 days	False aneurysm of profunda femoral artery	Ligation and excision	Good
ES	30	F	Stab wound of thigh	3 mos. and 8 days	False aneurysm of profunda artery	Ligation and excision	Good
LF	80	M	Laceration under left arm	6 yrs. and 6 days	Laceration of brachial artery with false aneurysm formation	Excision and end-to-end anastomosis	Good
WM	18	M	Stab wound left thigh	3 wks.	False aneurysm of left femoral artery	V excision	Good
AP	59	M	Fracture of right clavicle	3 yrs.	False aneurysm of right subclavian	Excision and ligation of subclavian artery	Good
EJ	22	M	Bullet wound of right thigh	12 days	False aneurysm of right femoral artery (coded as a-v fistula)	Resection 3-inch homograft from child's aorta-vein	Good dorsalis pedis pulsation
RT	56	M	Chip off steel wedge striking left wrist	2 wks.	False aneurysm of left radial artery	Excision with arterial repair	Good pulses
BMD	15	F	Laceration of wrist	5 wks.	Aneurysm of right ulnar artery	Excision with ligation	Good
					B. Incomplete Division (Simple Blood Loss)		
RK	38	M	Stab wound of left chest	5 hrs.	Laceration of internal mammary	Ligation	Good
RJB	21	M	Knife injury to left thigh	9 hrs.	Laceration of femoral artery and profunda femoral artery	End-to-end anastomosis	Good
OMJ	35	F	Surgery and irradiation to carcinoma of cervix 10 mos. age	Unknown	Surgery or radiation preceding iliac-enteric fistula	Resection and ligation	Good
LO	25	M	Stab of ulnar aspect of right arm	14 days	Partial severance	Ligation	Good
CH	23	M	Laceration of wrist	14 hrs.	Longitudinal laceration of radial artery	Repair of artery	Good

C. Puncture Wounds

SC	47	M	Shotgun wound of left leg and abdomen	14 hrs.	Lacerations of left femoral artery	End-to-end anastomosis	Good
NH	26	M	Shotgun wound of lower body	3 hrs., 30 mins.	Pellet wounds of femoral artery	Resections and end-to-end anastomosis	Good; no follow-up
FL	55	M	Carotid arteriogram	6 mos., 20 das.	Subintimal hemorrhage	Removal of hematoma	Fair
JS	32	M	Carotid arteriogram for pituitary adenoma	1 mo., 10 das.	Thrombosis of left internal carotid artery	Exploration	Poor (thrombosis)

D. Contusion

RL	29	M	Fracture of lower third of right femur	3 hrs.	Thrombosis of femoral artery	Removal of thrombus	No pulses but foot warm; pulses at last visit
RED	25	M	Dislocation of left tibia on femur	20 hrs., 15 mins.	Block of popliteal artery	Exploration of artery	Amputation
CEW	21	M	Compound fracture of distal femur	25 days	Thrombosis and angulation of distal femoral artery	Amputation	Amputation

E. Arterial Spasm and Kinking Including Compression

LS	4	F	Supracondylar fracture right arm	9 hrs.	Spasm of brachial artery	Fasciotomy	Good

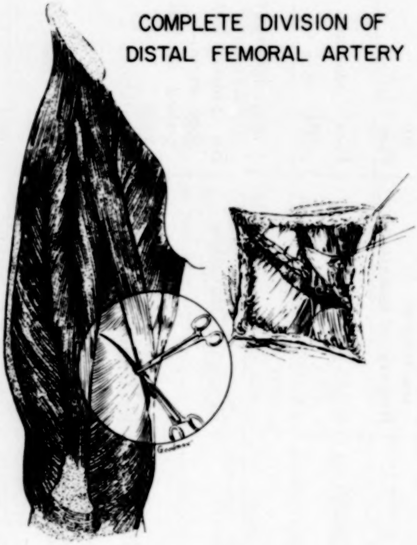
COMPLETE DIVISION OF
DISTAL FEMORAL ARTERY

Fig. 1. Case E. M. Note the complete severance of artery, veins and nerves

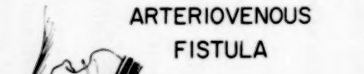
ARTERIOVENOUS
FISTULA
ARTERY
VEIN
ARTERY
VEIN

Fig. 2. Case M. C. This shows the site of an acute arteriovenous fistula due to a bullet wound.

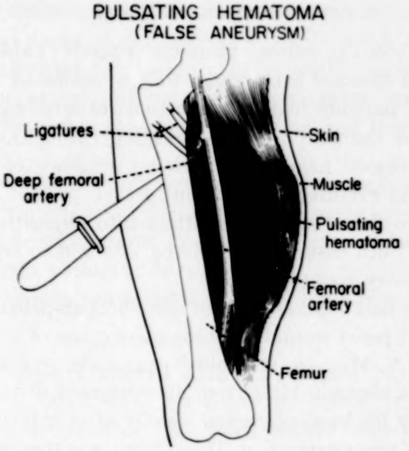

FIG. 3. E. S. Note the large space filled with old blood

emergency room of the University Hospital for a stab wound of the anteriolateral aspect of the right thigh. A suitable dressing was applied, and she was released. Six weeks later she was admitted with a tender, hot mass in the anteriomedial aspect of the right thigh. No definite area of fluctuation was noted. Having responded to heat and antibiotics, she was discharged with instructions to return if any similar episodes occurred.

Three weeks later she was readmitted with the same complaint. This time an incision was made and purulent material was obtained, in addition to old hematoma; such material was again evacuated a week or so later. Finally on the afternoon just before anticipated discharge from the hospital, she began to bleed steadily from the site of the original stab wound. This wound was, as stated, on the lateral aspect of the thigh; whereas, the incision and drainage had been done on the medial aspect. At exploration through the initial stab wound, a tremendous space between fascial planes was found filled with infected hematoma. The bleeding point was in the profunda femoral artery very close to the femur (Fig. 3). This artery was ligated above and below and then divided between ligatures.

This case represents an instance of prolonged morbidity due to delay in diagnosis. If the diagnosis had been made earlier, the patient would have been spared much time and hospitalization. Delay in diagnosis is a common circumstance where false aneurysms are concerned. Arteriography is now almost routinely employed to identify possible arterial damage in questionable circumstances.

Simple Blood Loss (Table I-B). There were five cases of partial division without the development of arteriovenous fistulas or false aneurysms—these patients having been operated upon soon after injury before arteriovenous fistulas and/or false aneurysms had developed.

PUNCTURE WOUNDS

There were four cases of solitary puncture wounds (Table I-C) of the arteries without evidence of external hemorrhage that necessitated surgical intervention. Two neurosurgical patients had had insertions of large-gauge needles into the carotid systems for the purpose of performing carotid arteriograms (Fig. 4). Both patients developed hemiplegia with no evidence of pulses distal to the puncture wound. At eventual exploration in each patient a subintimal hemorrhage was found to have forced the intima into apposition with the opposite side of the vessel. Both cases were explored late and in neither instance was a completely satisfactory result achieved.

Two other cases had solitary or multiple shotgun-pellet wounds of arteries. Thrombosis around pellet wounds was the chief cause of occlusion.

Illustrative case: N. H., a 26-year-old Negro male, was wounded in the lower body and legs by a shotgun blast from an estimated distance of 40 to 50 feet. When examined by his local physician shortly after injury no foot pulses were palpable in the left lower extremity. The patient was then sent to the emergency room of the University Hospital. Three and one-half hours after injury the posterior tibial and dorsalis pedis pulses were palpable in both extremities. There were scattered pellet wounds on the posterior aspect and upper one third of the right thigh. Numerous pellet wounds were located over the medial aspect of the upper thigh which was oozing in most areas. There was no brisk bleeding. On roentgen examination the pellets were found about the femoral artery, concentrated in one area of about 4 by 4 cm., but the pattern covered an area greater than 6 or 8 inches. There was some sensory deficit below the knee on the left, but no specific, localized nerve injury. In view of the fact that the pulses were not palpable soon after injury and definitely were palpable on admission to this hospital, it was felt that he probably had anteriospasm which had caused the pulses to disappear. On this basis he was treated conservatively, placed on antibiotics and observed. Pulses were checked frequently until 5 a.m. the morning after admission, at which time they were noted to be palpable. At 7 a.m., however, no pulse was palpable in the left foot, and the left lower extremity below the knee was definitely cooler than the right. He was seen by several consultants at that time, and it was felt that paravertebral block would be in order to see if the vessels were again in spasm or if there was actual occlusion in the vessel. A paravertebral block was done without benefit. The patient was then taken to the operating room, and an exploration of the left femoral artery was performed. Several wounds of the femoral artery were discovered in the middle one third of the thigh, and a large thrombus had formed in the artery, completely occluding it. This site was opened, the damaged portion was resected, and the thrombus was removed. An end-to-end anastomosis was performed, but a thrombus formed in the artery while the anastomosis was being done. A small incision was made distal to the anastomosis, and the thrombus was removed. After closure of this slit, the patient had good pulse distally, and he was sent to the ward in good condition. Later that night, however, the pulses disappeared and the patient was returned to surgery and the artery was re-explored. Another large thrombus had formed at the site of anastomosis. The anastomosis was taken down, the thrombus was removed, and a second anastomosis was performed. At the conclusion of the procedure, another thrombus had formed below the anastomosis; another incision was made in the artery, and the third thrombus was removed. The patient had good pulses at the end of these two procedures and thereafter all pulses remained excellent.

On the day following the surgery the patient had an apparent foot drop, being unable to dorsiflex the left foot. Neurosurgical consultants believed that the neural deficit would be temporary, since it had developed late and was likely due to edematous compression of fibers within the nerve. This proved to be so, for improvement in muscle power was evident within a few days.

CONTUSION

There were three cases of arterial contusion, (Table I-D), a type of injury that is frequently associated with soft-tissue or skeletal injury (17, 20). Two of our cases required amputation; the third patient regained warmth in the foot but foot pulses remained absent. These cases were explored late; quite possibly early exploration would have yielded better results.

Illustrative case: R. L., a 29-year-old Negro male, was seen in the emergency room at the University Hospital about three hours after an automobile accident, having sustained a fracture of the lower one third of the right femur. The blood pressure was within normal limits. Examination of the extremities revealed swelling and tenderness over the right lower thigh and there was false motion in this area. All pulses were present in the left leg, but no pulses could be palpated below the femoral artery on the right, and this foot was cold. X-ray examination revealed a transverse, simple fracture of the distal third of the right femur, and the patient was placed in modified Russell's traction. A paravertebral block with procaine was given in an attempt to restore pulses in the right lower extremity, but this produced no discernible effect. Twenty-four hours after admission the patient was taken to the operating room with the plan of inserting a Hanson-Street nail for stabilizing the bone fragments and to explore the right femoral artery. It was found that the femoral artery was pulseless distal to the fracture site and a firm intra-arterial thrombosis could be palpated through the wall. The vessel was opened and an attempt was made to aspirate the thrombus. However, even after removal of the clot no foot pulses developed. Distal thrombosis had undoubtedly occurred. Retrograde flush (4) was not employed. Fortunately the foot remained viable, and the patient was able to walk without difficulty. No trophic changes were noted at the last clinic visit.

This represented a favorable result where it was not possible to restore normal arterial flow.

ARTERIOSPASM

Arteriospasm (Table I-E) can be severe and may lead to changes which result in gangrene (3, 7, 14). L. S., a 4-year-old Negro female, was admitted to the University Hospital after having fallen off a porch injuring her right elbow. X-ray revealed a typical supracondylar fracture, and at this time the radial

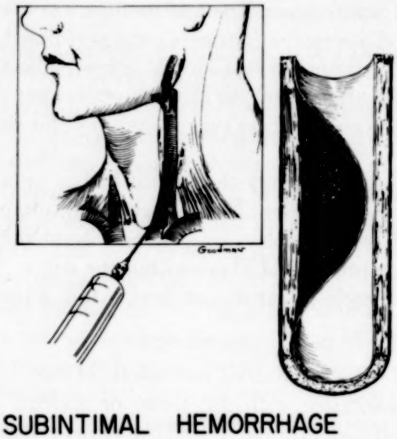
SUBINTIMAL HEMORRHAGE
Goodman

Fig. 4. The clot has dissected away the intima causing intimal apposition

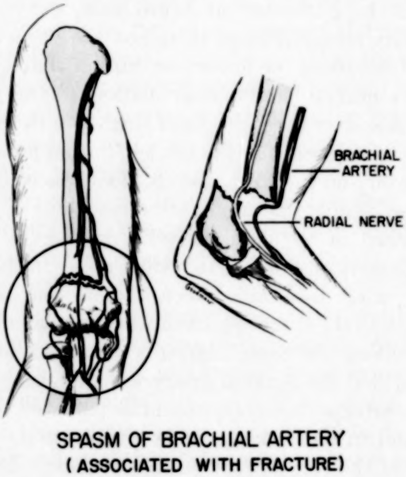
BRACHIAL ARTERY
RADIAL NERVE
SPASM OF BRACHIAL ARTERY
(ASSOCIATED WITH FRACTURE)

Fig. 5. L. S. The arterial spasm was apparently due to irritation from the fracture site

pulses were palpable bilaterally, and equal. The patient was taken to the fracture room and an attempt was made to manipulate the fracture under general anesthesia. When the manipulation was performed, however, the right radial pulse disappeared and did not return. Accordingly, the antecubital fossa was explored. The brachial artery was noted to be in severe spasm, and it was dissected out for a length of approximately 6 cm. (Fig. 5). Following this the pulse returned to normal. Follow-up of the case revealed satisfactory bony union with the maintenance of a good radial pulse. Locally applied papaverine solution (2.5%) has been found to relieve arteriospasm in an exposed vessel (7, 13).

DISCUSSION

DeBakey and Simeone (5), reviewing a large new series of arterial injuries in Europe in World War II, noted that the over-all amputation rate was approximately 50 per cent. The amputation rate varied from 75 per cent where the femoral artery was involved to as low as 30 per cent where the brachial artery was involved. Without associated soft-tissue injury or fracture, the incidence was somewhat lower. Hughes (10), in the Korean War, found that the amputation rate for ligated vessels was approximately 50 per cent, the same as in World War II. After the institution of direct reconstructive techniques, however, the amputation rate dropped to approximately 13 per cent. Morris, et al. (19), in an analysis of their experience with 220 acute arterial injuries over a period of 10 years, reported that there was a restoration of peripheral pulses in 86 per cent of their cases. In their series of 220 cases there were 15 amputations and 25 deaths. In our series pulses were restored in approximately 85 per cent of the cases. There were no deaths. Amputation was required in three (7%) extremity injuries.

GENERAL PRINCIPLES OF MANAGEMENT

Diagnosis. As has been emphasized, one of the most important and frequently one of the most difficult objectives to achieve in the management of arterial injury is that of establishing a sufficiently accurate diagnosis regarding the actual presence and type of injury. Contusion of an artery may be followed by varying degrees of arteriospasm, during which distal pulses may not be palpable. During this period of spasm, when the lumen of the vessel is markedly reduced in caliber and the intima perhaps damaged, thrombosis may occur. Arteriography (15) may be helpful in distinguishing simple spasm, thrombosis and loss of arterial continuity. At times paravertebral sympathetic nerve block is helpful. If indicated or where doubt exists, exploratory surgery should be performed.

Of course spasm, contusion and thrombosis are not likely to be confused with loss of arterial continuity where severe hemorrhage, a false aneurysm (pulsating hematoma) or an arteriovenous fistula with its characteristic thrill and bruit is in evidence. Perhaps the most salient feature of successful diagnosis is that of suspecting that arterial injury exists. The appropriate diagnostic steps will then usually follow in orderly sequence. Unnecessary delay markedly reduces the chance of successful surgery in many instances (18).

Operative Techniques. The first requirement in the operative management of an arterial injury is that of minimizing further blood loss and the restoration of an adequate circulating blood volume. If the wound involves an extremity or the neck, firm point pressure will usually suffice to control the bleeding. If hemorrhage has ceased, as with thrombosis, false aneurysm or arteriovenous fistula, the surgical approach may be chosen with more deliberation. Basically, a suitable incision is employed that will afford control of the artery (and vein where involved) both above and below the probable site of injury. Once tapes or clamps have been passed around the entering vessels both above and below, the site of injury may be approached rapidly and with confidence, since the tapes can be tightened at any time to prevent excessive blood loss. Not infrequently important nerves lie in close proximity to major arterial and venous trunks, and appropriate precautions must be taken to avoid injury to such structures.

Contusion with spasm and subsequent thrombosis can be one of the most unsatisfactory types of arterial injury to treat. This is because the segment of damaged vessel may be quite extensive, often with thrombotic occlusion of collateral channels. There may exist subintimal clots which have displaced the intima into the lumen, subadventitial hemorrhage which has displaced the remainder of the vessel wall inward, or simple intraluminal clot due to intimal trauma. Regardless of the mechanical interference which hematoma and/or thrombosis has produced, with associated spasm, technical management must be such as to restore pulsatile flow where possible in all significant arteries. Such management may on different occasions consist of various of the following. First, severe spasm may be relieved by locally applied 2.5 per cent papaverine hydrochloride solution (7, 13). If thereafter pulsatile flow is restored distal to the site of damage, nothing further need be done. If a subadventitial hematoma is found, this should be evacuated and the state of arterial flow then reassessed. If a subintimal or intraluminal thrombus is palpated through the vessel wall, arteriotomy is indicated. At times a transverse incision results in less luminal constriction at the time of closure than does a longitudinal incision. In the event the clot cannot be removed successfully, with restoration of pulsatile flow, the diseased segment should be resected with primary end-to-end anastomosis or the interposition of a vein graft or other suitable material. But whatever steps are required, the vessel itself should always be handled gently and fine atraumatic suture material used. We use 4-0 arterial silk for larger arteries and 5-0 silk for anastomoses of smaller arteries such as the radial and ulnar vessels. With proper care in suturing and with avoiding undue trauma to the intima, we have found that pulsatile flow can be regularly re-established in even small arteries.

When it is found necessary to resect a segment of artery, mobilization of the vessel for several centimeters above and below with division of perhaps one or two collateral branches plus flexion of the extremity will provide additional length and so reduce the tension on the suture line at the anastomosis.

Simple laceration with incomplete or complete division of the vessel, if treated soon after the injury, is usually repaired easily in vessels of significant size. The ends are located following proximal and distal control of the artery, and primary anastomosis is performed after suitable freshening of the margins and the removal of any intraluminal clot. We usually employ a continuous over-and-over or baseball stitch for the anastomosis of larger vessels; however, occasionally the continuous everting mattress suture is employed. For small vessels interrupted sutures are used. If a considerable amount of arterial substance has been destroyed and primary anastomosis is not possible without undue tension, a graft of suitable type must be interposed. We and others (22) have repaired several radial arteries readily and successfully.

Aneurysms may, of course, be true or false in type. Again, a true aneurysm is one which has developed because of damage to the arterial wall but where some portion of the arterial wall remains intact at all points. A false aneurysm or pulsating hematoma represents a lesion in which continuity of the arterial wall has been lost at some point; that is, blood may flow out of the artery into the hematoma which is walled off by surrounding fibrous tissue reaction.

But in any event, both true and false aneurysms are approached with the same objective; namely, the excision of the defective portion of the artery with restoration of blood flow. The chief difference between the two, from the standpoint of technical management, lies in the fact that the arterial defect is often quite short in the case of a false aneurysm; whereas, it may be much more extensive in the instance of a true aneurysm. But in any event, the surgical approach is the same; one gains control of the vessel proximally and distally and then does what is required to excise the damaged segment and restore blood flow. At times only one portion of the arterial wall need be excised but more commonly it is preferable clearly to excise an entire segment of the vessel.

Traumatic arteriovenous fistulas no longer pose the complicated problem which they formerly did. A decade ago the formation of such a lesion, secondary to a knife or gunshot wound, was attended by a delay of from six weeks to six months to allow sufficient collateral circulation to develop to permit quadruple ligation and excision without precipitating gangrene of the extremity distally and hopefully without subsequent intermittent claudication. Following the experience gained in the Korean War, however, these lesions were boldly attacked as soon as discovered, with arterial and frequently venous reconstruction. The results of such measures have been extremely gratifying. In our hospital we have not treated a traumatic arteriovenous fistula of significant size by quadruple ligation and excision since 1955. All such lesions have been managed by arterial, and usually venous, repair just as soon as they were discovered. In no instance has distal pulsatile flow not been established; there has been no subsequent intermittent claudication; and no extremities have been amputated because of this particular lesion.

Causalgia. One of the more distressing complications of arterial trauma is the postinjury pain syndrome termed causalgia. This discomfort arises in tissues innervated by the sympathetic nervous system. Usually the painful state is associated with injury to bone, artery or nerve. In addition to pain, atrophy of the affected part may be a prominent physical finding. Whether this is due to reflex spasm or disuse atrophy is not clearly known.

Treatment usually involves interruption of the sympathetic nerve supply to the part involved (1, 6, 16, 23). This is followed by varying degrees of success.

Causes of Failure in Arterial Repair. While prompt and proper repair of injured arteries is rewarded by spectacular degrees of success, failures will occur at times, though with precautions these can be minimized. The chief causes of failure are: (1) excessive delay in operative intervention, (2) extensive other soft-tissue and bony defects which render arterial reconstruction either impossible or futile, (3) inadequate technical surgery such as constriction or undue tension at the line of anastomosis, or (4) postoperative thrombosis due to intimal damage secondary to the original trauma or to operative manipulation.

In civilian life, excessive delay is often the result of procrastination on the part of attending physicians and, to this extent, such delay can be minimized. Unquestionably further advances in the management of muscle, nerve and bone damage will increase the scope of successful arterial repair in massive trauma. The need for technically adequate arterial surgery is accepted, and such experience can be obtained readily in the animal laboratory. Postoperative thrombosis will, however, pose a problem to all surgeons upon occasion. Perhaps the most important point to be made is that immediate re-exploration should be performed where doubt exists. The recent wound in the neck or an extremity is easily opened under local anesthesia, and the clot may be removed through either the previous anastomosis or, often preferably, through an arteriotomy incision, either above or below the previous suture line. At times the retrograde flush technique or manual stripping is useful, until good back-bleeding from the distal segment of the vessel has been established. Thereafter the arteriotomy incision is closed using very fine suture material and very small bites, so as not to constrict the lumen. Local and systemic use of heparin may be employed, but if this agent is used the wound should be drained. In brief, on one occasion permanent pulsations were achieved only after the third arterial exposure and evacuation of recurrent thrombi.

SUMMARY AND CONCLUSIONS

1. A series of cases treated by the newer concepts of early, direct arterial repair has been presented.
2. Early diagnosis and repair of all arterial injuries is important if the late sequelae of arterial occlusion are to be avoided.
3. There rarely is a need for delaying repair of arteriovenous fistulas.
4. Direct arterial reconstructive techniques are applicable in most isolated arterial injuries involving the extremities, and repair should be routine where tissue integrity or function might otherwise be impaired.
5. Certain principles of diagnosis and operative techniques are emphasized.

REFERENCES

1. Barnes, R.: The role of sympathectomy in the treatment of causalgia. J. Bone & Joint Surg., **35-B:** 172–180, 1953.
2. Bradford, B., Jr. and Moore, M. J. Vascular injuries in war. Surg. Gynec. & Obst. **83:** 667–673, 1946.
3. Cohen, S. M. Traumatic arterial spasm. Lancet, **1:** 1–6, 1944.
4. Crawford, E. S. and DeBakey, M. E. The retrograde flush procedure in embolectomy and thrombectomy. Surgery, **40:** 737–746, 1956.
5. DeBakey, M. E. and Simeone, F. A. Battle injuries of the arteries in World War II; an analysis of 2,471 cases. Ann. Surg., **123:** 534–579, 1946.
6. DeTakats, G. Causalgic states in peace and war. J.A.M.A., **128:** 699–704, 1945.
7. Edwards, W. S. and Lyons, C. Traumatic arterial spasm and thrombosis. Ann. Surg., **140:** 318–323, 1954.
8. Elkin, D. C. The treatment of aneurysms and arteriovenous fistulas. Bull. New York Acad. Med. **22:** 81–87, 1946.
9. Holman, E. Fundamental principles governing the care of traumatic arteriovenous aneurysms. Angiology, **5:** 145–166, 1954.
10. Hughes, C. W. Arterial repair during the Korean War. Ann. Surg. **147:** 555–561, 1958.
11. Hughes, C. W. and Jahnke, E. J., Jr. The surgery of traumatic arteriovenous fistulas and aneurysms; a five-year follow-up study of 215 lesions. Ann. Surg., **148:** 790–797, 1958.

12. Hunter, W. Observations upon a particular species of aneurysm. Med. Obs. Soc. Phys., **2:** 390–414, 1762 (Cited by Holman, E. Arch. Surg., **7:** 64, 1923).
13. Jahnke, E. J., Jr. and Howard, J. M. Primary repair of major arterial injuries; report of fifty-eight battle casualties. A.M.A. Arch. Surg., **66:** 646–649, 1953.
14. Kinmonth, J. B. The physiology and relief of traumatic arterial spasm. Brit. M. J. **1:** 59–64, 1952.
15. Logan, W. D. and Goudelock, W. J. Arteriographic errors in localization of acute arterial obstruction; case report and experimental studies. Surgery, **43:** 974–978, 1958.
16. Mayfield, F. H. and Devine, J. W. Causalgia. Surg. Gynec. & Obst., **80:** 631–635, 1945.
17. McKenzie, A. D. and Sinclair, A. M. Axillary artery occlusion complicating shoulder dislocation; a report of two cases. Ann. Surg., **148:** 139–141, 1958.
18. Miller, H. H. and Welch, C. S. Quantitative studies of the time factor in arterial injuries. Ann. Surg., **130:** 428–438, 1949.
19. Morris, G. C., Jr., Beall, A. C., Jr., Roof, W. R. and DeBakey, M. E. Surgical experience with 220 acute arterial injuries in civilian practice, Houston, Texas. Am. J. Surg., **99:** 775–781, 1960.
20. Rob, C. G. and Standeven, A. Closed traumatic lesions of the axillary and brachial arteries. Lancet, **1:** 597–599, 1956.
21. Seeley, S. F., Hughes, C. W., Cook, F. N. and Elkin, D. C. Symposium on vascular problems; traumatic arteriovenous fistulas and aneurysms in war wounded, a study of of 101 cases. Am. J. Surg. **83:** 471–479, 1952.
22. Shaw, R. S. Reconstructive arterial surgery in upper-extremity injuries. J. Bone & Joint Surg. **41-A:** 665–673.
23. Shumacker, H. B., Jr. Causalgia. III. A general discussion. Surgery, **24:** 485–504, 1948.
24. Shumacker, H. B., Jr. The problem of maintaining the continuity of the artery in the surgery of aneurysms and arteriovenous fistulae. Notes on development and clinical application of methods of arterial suture. Ann. Surg., **127:** 207–230, 1948.
25. Spencer, F. C. and Grewe, R. V. The management of arterial injuries in battle casualties. Ann. Surg., **141:** 304–313, 1955.

DISCUSSION

Dr. Curtis P. Artz (Jackson, Mississippi) (Closing): It is obvious that we have not presented anything unusually new on arterial injuries. Our purpose was to emphasize the value of a vigorous vascular program where every surgical resident is trained in the management of arterial injuries.

Our residents are led to the laboratory and given an opportunity to become technically proficient in vascular anastomosis.

When patients with major vessel injury are seen in the emergency room, the one way to conserve vessel length is to use a Potts or other type of vascular clamp on the vessel, rather than a hemostat.

The use of a hemostat on the severed vessel may lose almost 2 cm. that might be saved by the application of a vascular clamp.

Early exploration is recommended. If there is any indication that there might be a vascular injury, although one might suspect it is only spasm, the vessel should be explored.

Finally, it is important to débride the wound about the vascular injury. So often we do a good vascular repair but an inadequate débridement of the wound. It is important to remove all the devitalized tissue if infection is to be prevented. One of the greatest deterrents to good vascular healing is infection.

TRAUMA NEWS

Edited by
JAMES K. STACK, M.D.

SURGEONS' AWARD FOR DISTINGUISHED SERVICE TO SAFETY*

PURPOSE:

Recognition of outstanding service to safety by surgeons or surgical organizations.

OBJECTIVES:

1. Strengthen the work of surgical organizations by identifying and enhancing their emphasis on the interlocking problems of the prevention and restoration of accidental injuries.
2. Strengthen the work of safety councils through the increased participation of surgeons in organized accident prevention activities.
3. Continue progress in the development of criteria to ascertain the effectiveness of activities conducted for the prevention of accidents.

SPONSOR:

National Safety Council.

BASIS:

Individual or organizational service and activity which make outstanding contributions to the prevention of accidents, establish or demonstrate methods and results adaptable to other individuals or groups, or result in stimulating others to undertake or take part in safety projects or programs.

In general, the activities recommended in the Joint Action Program will serve as the basis for accident prevention work done by many surgeons and the surgical organizations. The contributions made by the individual or the organization to achievement of subgoals in this program will normally be the work being evaluated.

PERIOD:

Individual's or organization's years of work on safety.

RULES:

1. Nominee must be a surgeon or a surgical organization (or a unit thereof).
2. Nominations may be made by an organization or an individual.
3. Nominations should be made privately, without publicity.
4. Nominations must consist of official entry blank accompanied by pertinent supporting exhibits.

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* This award is an activity of the Joint Action Program of the American Association for the Surgery of Trauma, the American College of Surgeons, and the National Safety Council. Blanks for making nominations may be obtained from the National Safety Council, 425 North Michigan Avenue, Chicago 11, Illinois.

5. Nominations must be submitted by August 1 for an award to be made in that calendar year.
6. Nominations should be sent to the Director, Public Safety Department, National Safety Council.
7. The complete record of the awards made and the reasons for such awards will be kept on file in the National Safety Council offices.

JUDGES:

The judging will be done by the Policy Committee for the Joint Action Program of the American College of Surgeons, American Association for the Surgery of Trauma, and the National Safety Council (excluding individuals or organizations nominated).

CRITERIA:

Program organization, activity, and accomplishments may be evaluated. For example, a surgeon might be the first one to recognize a new accident hazard; involve his associates in a study of this problem; report his findings by writing scientific papers for professional periodicals, and speaking at professional and other meetings; take an active part in safety council work; and participate in committee work so that other organizations can be alerted to the problem and know how they can help to prevent such accidents.

SCHEDULE:

Normally, the nominations are to be received during the first half of the year. The judging will take place in the following months, and the award made at an appropriate occasion in the fall.

Normally only one Surgeons' Award for Distinguished Service to Safety will be made in any one calendar year.

PRIMARY STAFF COORDINATION:

Ralph Kuhli, Staff Representative, Joint Action Program

DESCRIPTION OF AWARD:

Plaque, suitably engraved.

PRESENTATION:

Presented at occasions closely allied with the winner's activities and interests, but no later in the year than the time of the National Safety Congress of the National Safety Council, or the Clinical Congress of the American College of Surgeons, or the Annual Session of the American Association for the Surgery of Trauma.

January, 1961

EDITORIAL

Does the Injured Patient Receive Optimal Care?

Elsewhere in this journal is a report on the care of the Injured Patient. It should cause us to study and to appraise what we are doing for the severely injured. Is it a true picture? If it is, why is it and what can be done about it?

Van Wagoner in his survey set very low standards for what he called adequate care but even these were not met in 16–32% of the cases. It is probably true that he has drawn data from hospitals which are usually inarticulate and whose results in all fields are below those of the larger clinics and hospitals. Many of these lag ten years behind the foremost in adoption of medical advances as pointed out by Whipple years ago. One does not need to look far afield, however, to see that "Trauma" is a stepchild and that cancer, heart disease et al. are favored in the attention given by the public and medical profession. How much time is spent teaching trauma in medical schools? How many of the large University Hospitals have an ambulance service? Does the ward and pavilion population of the teaching centers reflect the relative incidence of trauma or the greater interest in elective surgical problems? Does it reflect the needs of the public for medical care or medical interest in rarity? One must concede that trauma does not get its just measure of attention.

Why is trauma care unpopular? The injured patient either intrudes on an already busy day or he demands care at night or on a weekend. He may or may not be an operative case and his convalescence may be prolonged. He does not come through the ordinary channels of referral but rather through assignment and while the patient may be grateful for his excellent care the surgeons will not therefrom build a practice. It would serve the surgeon better to treat, study and write in an elective field where his writings will attract patients from his colleagues.

If the surgeon, in spite of the compelling reasons mentioned above, enters this field what other obstacles beset him? Some are inherent, some could be corrected. The severely injured patient besides coming at an inconvenient time comes in a condition which often makes evaluation and diagnosis difficult. He cannot talk or will not because all he wants is relief. He can't be turned and moved about for thorough examination. His condition changes rapidly. If he has been unwise enough to be injured or become critically ill on Friday afternoon then many determinations must await reporting until Tuesday afternoon, if it is a holiday weekend. His surgeon has probably seen a case like this before but it was sometime ago, he cannot remember it too well, and the knowledge which could have been derived from an autopsy of that case was denied him because the body was removed elsewhere since the legal aspects have priority over the medical.

What hope is there for improvement in the care of the severely injured? Many surgeons have noted some of the unhappy truths in the foregoing. They have formed organizations. These educate and exchange information. Some outstanding surgeons have contributed to the pathological physiology of trauma. Surgeons in other fields have been the beneficiary of national organizations supplying funds for research and education. Trauma services with general surgeons and specialists are being organized but the bright new day for the injured patient will not dawn until those with authority, influence and responsibility realize the comparative deficit which now exists in the care of the Injured Patient.

WILLIAM H. CASSEBAUM, M.D.

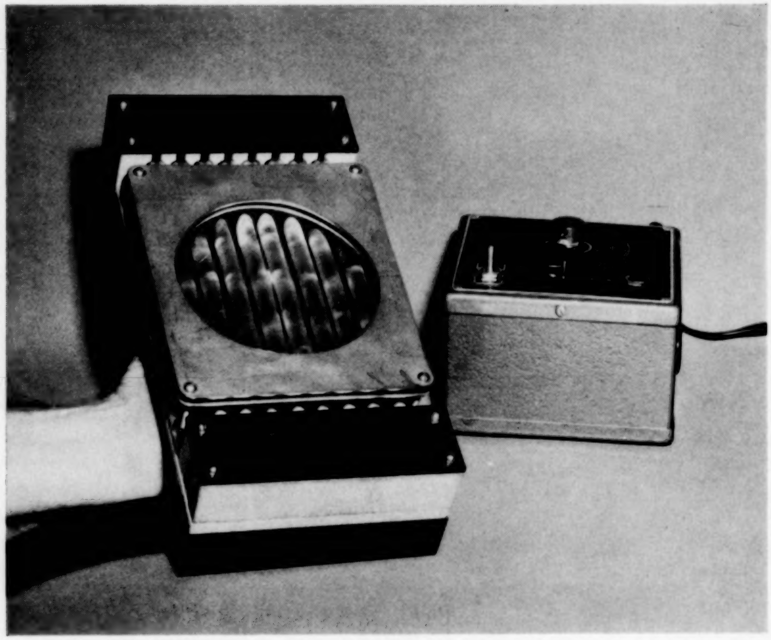

Fig. 1

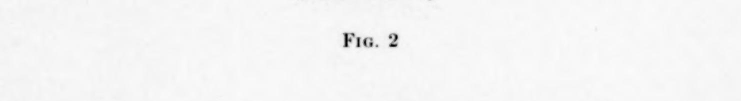
RELATIVE SPECTRAL DISTRIBUTION OF RADIANT SOURCE
VISIBLE ENERGY
4000
7000
10,000
15,000
20,000
25,000
30,000
35,000
40,000
45,000
50,000
(ANGSTROMS)

Fig. 2

AN EVALUATION OF LOCAL THERAPY FOR SECOND DEGREE BURNS

A Preliminary Report

JOSEPH FOREMAN, M.D., I. H. SOKOLIC, M.D. AND JOHN M. HOWARD, M.D.

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SCOPE AND PURPOSE

The problem of treatment of minor burns, particularly in the hands of lay personnel, was investigated by a comparative evaluation of ten different burn regimens each of which has been more or less advocated in the medical literature. The regimens included: (1) a bland ointment, (2) vaseline gauze, (3) a broad spectrum antibiotic, (4) an antiseptic, (5) a plastic spray, (6) a quatarnary ammonium soap, (7) a topical anesthetic, (8) proteolytic enzymes, (9) materials aiding coagulation, (10) an inert powder.

METHOD

In this experiment, standard second degree burns were induced in one hundred volunteers (6). Four burns were induced in each subject, one on the lateral aspect of each thigh and one on the volar aspect of each forearm. In each case, the burn on one limb served as a control for the treated burn on the opposite limb. The control burn was managed in an identical manner with the experimental burn, with the exception that no medication was applied to the control wound, i.e. when a medication was applied to an experimental wound and covered with a dressing, then the control wound was also covered with the same type of dressing, and when the experimental wound was left undressed after the application of medication, then the control wound was also left open. By using each volunteer as his own control, it was possible to eliminate the biological variables inherent in different individuals which might influence the healing process. By eliminating the other variable—that of the depth and size of the burn itself—the only variable left to be considered was the method of treatment.

In order to induce a consistently standard, predictable, reproducible burn so that control and treated burns would be identical, a portable radiant energy source was designed and constructed. This apparatus was composed of a bank of eight nitrogen-filled quartz tubes with tungsten filaments, which provided 4000 watts of radiant energy. Eighty per cent of peak output was reached in 2 seconds. (See Figure 1.) This was possible because of the low mass of the fila-

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Read before the Twentieth Annual Session of The American Association for the Surgery of Trauma, Coronado, California, October 5-7, 1960.

TABLE I

Therapeutic Agents Tested

Aluminum powder
Rezifilm spray (a methacrylate resin containing tetramethylthiuram disulfide)
Gelfoam pads
Papain and chymopapain 10,000 u/gm. of ointment
Hibitane ointment (1% bis-(P-chlorophenyl-Diguanido)-Hexane (Chlorhexidine)
Vaseline gauze
Carbowax 1500 as a water soluble ointment
Xylocaine 1% in carbowax 1500
Oxytetracline powder 30 mgm. per gram of powder base (milk sugar with methylparaban)
3% hexachlorophene liquid soap

ments, which could be operated at more than 3000°F. Also, the quartz tubes passed most of the energy immediately without being raised to this filament temperature. Almost all of the energy emitted was in the infra-red spectrum, a small portion appearing as visible light. (See Figure 2.)

The exposure time was varied by means of an electrical timer, calibrated in 0.25 second increments. The energy output of the device was such that only 1.5 seconds were required to produce a deep second degree burn (4). Induction of the burn was so rapid that reflex withdrawal by the subject from the heat source presented no serious problem and local anesthesia or premedication was unnecessary, permitting close simulation of clinical flash burns.

All thigh burns were 10 cm. in diameter, and all arm burns were 6 cm. in diameter. The distance from the quartz tubes to the skin surface was 1.7 cm. in all cases.

Ten substances were chosen for study. (See Table 1) (1, 2, 3). Each of the ten experimental series consisted of a total of twenty burns—ten arm burns and ten thigh burns—each with its corresponding control in the same individual.

In the series utilizing gelfoam pads, papain ointment, hibitane ointment, vaseline gauze, carbowax ointment, xylocaine ointment and oxytetracycline powder, both the control and experimental burns were dressed with sterile gauze pads. In the other three series, both experimental and control wounds were left exposed, and no dressings were used.

The following parameters were evaluated in an attempt to determine the effect of the medication on wound healing: (1) regional lymphadenopathy—axillary adenopathy as an index of local reaction in the arm burns and inguinal adenopathy as an index in the thigh burns. The degree of adenopathy was expressed in a rough quantitative manner as "0", +1, +2, +3, or +4; "0" denoted the absence of any palpable nodes, "+1" denoted the presence of one small node, the size of a pea or less, "+2" one node larger than pea-size or two nodes, "+3" indicated multiple shotty nodes or three to four larger nodes, while "+4" signified the presence of matted adenopathy. (2) Diurnal oral temperatures—as an index to generalized body reaction to inflammation. (3) Wound pain—taking into consideration duration of pain following burn induction, degree of pain expressed as "0", +1, +2, +3, +4, "0" denoting complete absence of pain, +1 denoting pain on motion, "+2" denoting pain at rest, "+3" indicating pain at rest and on motion, and "+4" indicating pain severe enough to require analgesic medication for relief. (4) Edema of the wound—as measured by circumference of the limb. (5) Quantitative study of the extent and type of bacterial contamination. (6) Serial color photography with planimetry measurements to determine the rate of healing as judged by the degree of re-epithelialization. Wound healing was considered complete when the entire surface of the burn was covered with epithelium and when all crusts had fallen off or were washed off. In addition, the times were determined at which the burns were 50%, 75%, and 90% healed.

Before the burns were induced oral temperature readings were recorded and preliminary regional lymphadenopathy determinations made. Within 10 to 20 seconds after induction of the burn an area of erythema appeared corresponding to the shape and size of the aperture. Immediately thereafter, the circumference of the limb was measured at the distal border of the burn wound. All subsequent circumferential measurements were made at the same point for serial comparisons.

Approximately two minutes post-burn the medication to be tested was applied. The control burn was managed in an identical manner, except that no medication was applied. If medication were applied to the experimental burn and the wound left open, then the control wound was also left exposed.

Daily temperature readings were taken at 8:00 A.M. and 3:00 P.M. If dressings were used, they were undisturbed for seven days. At the end of seven days, the dressings were removed and the medication gently washed off the wound. At this time comparative photographs of the burns were made, circumferential measurements of the limbs were taken, regional adenopathy was measured, and subjective pain was evaluated. Comparison of pain and light touch sensation between normal skin and the burned areas, both in the control and experimental wound, were also made. Following parametric determinations, dressings and medications were reapplied by the assistant. This process was repeated at intervals of two days until healing of the burns was complete.

On the ninth post-burn day, cultures of all burns were taken with a multi-pointed metal brush. The points of the brush were touched to the wound and then impressed into the blood agar plate. This method allowed discrete, easily countable colonies to grow out and provided a quantitative estimate of the degree of bacterial contamination and/or infection. The culture plates were incubated for 48 hours, photographed, the colonies counted and the type of organisms present identified by standard bacteriologic methods.

RESULTS

In compiling the results of the statistical study, it must be pointed out that not all of the subjects are included in the final analysis. Some of the subjects voluntarily dropped out of the experiment before healing was complete. In one subject, a severe allergic response to the medication used necessitated termination of his study. In several cases severe superimposed infection requiring hos-

TABLE II

Effect of Local Therapy on Wound Healing

	50 %				75 %				100 %			
	No. of trials	Mean controls	Mean treated	P-value	No. of trials	Mean controls	Mean treated	P-value	No. of trials	Mean controls	Mean treated	P-value
Aluminum Powder	20	21.3	19.9	No	20	26.6	25.3	No	20	38.9	37.3	−.15
Plastic Spray	20	19.0	22.9	Incr. 1% Level	20	24.3	27.4	Incr. 2% Level	20	36.8	37.7	.30
Vaseline Gauze	14	21.1	19.9	No	14	28.6	26.4	No	16	44.8	37.3	−.05
Gelfoam Pad	18	18.7	19.3	No	18	23.9	25.3	No	20	35.9	37.5	.20
Papain and Chymopapain	18	14.2	13.9	No	18	19.3	19.7	No	18	32.4	32.9	.35
Hibitane	20	17.0	16.7	No	20	21.5	21.1	No	20	32.0	32.2	.45
Xylocaine 1%	17	19.1	19.2	No	17	24.2	25.8	No	18	32.9	34.8	.15
Terramycin Powder	20	16.9	16.9	No	20	22.9	22.2	No	20	33.7	34.2	.45
Carbowax Base	18	17.5	15.6	No	18	21.8	20.1	No	18	32.7	32.1	−.45
3% Aqueous Hexachlorophene	16	18.3	18.1	No	16	24.4	22.8	No	18	34.7	31.6	−.05

TABLE III

Effect of Therapy on Quantitative Estimation of Subjective Pain

	No. of Trials	Mean Value Controls	Mean Value for Treatment	Significant Difference
Aluminum Powder	20	56.8	42.4	−.05
Plastic Spray	20	25.8	36.5	.30
Vaseline Gauze	16	52.4	61.1	.15
Gelfoam Pad	20	30.1	32.1	.50
Papain and Chymopapain	18	25.9	28.9	.30
Hibitane	20	40.7	15.0	−.01
Xylocaine 1%	18	42.5	39.8	−.35
Terramycin Powder	20	50.6	46.3	−.35
Carbowax Base	18	74.0	53.1	−.10
3% Aqueous Hexachlorophene	18	56.7	58.8	.45

TABLE IV

Effect of Local Therapy on Regional Adenopathy

	No. of Trials	Mean Value of Controls	Mean Value for Treatment	Significant Difference
Aluminum Powder	20	0.02	0.04	.45
Plastic Spray	20	0.55	0.43	−.30
Vaseline Gauze	15	0.49	0.70	.05
Gelfoam Pad	20	0.07	0.02	−.30
Papain and Chymopapain	18	0.21	0.53	.01
Hibitane	20	0.15	0.30	.15
Xylocaine 1%	17	0.52	0.52	—
Terramycin Powder	20	0.66	0.44	−.025
Carbowax Base	18	0.69	0.54	−.30
3% Aqueous Hexachlorophene	18	0.51	0.43	−.25

TABLE V

Effect of Local Therapy on Bacteriologic Contamination

	No. of Trials	Mean Value of Controls	Mean Value for Treatment	Significant Difference
Aluminum Powder	20	2.35	2.45	>.05
Plastic Spray	18	2.56	2.00	>.05
Vaseline Gauze	16	3.1	3.8	.15
Gelfoam Pad	18	2.89	3.17	>.05
Papain and Chymopapain	8	2.3	2.8	>.05
Hibitane	20	2.90	1.55	.01
Xylocaine 1%	17	3.5	3.3	−.30
Terramycin Powder	20	3.4	3.7	.20
Carbowax Base	17	3.6	3.6	—
3% Aqueous Hexachlorophene	18	3.4	2.9	−.15

TABLE VI

Effect of Local Therapy on Wound Swelling

	No. of Trials	Mean Value of Controls	Mean Value for Treatment	Significant Difference
Aluminum Powder	20	6.4	6.5	.45
Plastic Spray	20	6.5	5.6	−.20
Vaseline Gauze	15	4.5	7.1	.05
Gelfoam Pad	20	6.2	6.0	−.40
Papain and Chymopapain	18	5.3	6.3	.05
Hibitane	20	4.5	4.8	.40
Xylocaine 1%	17	4.6	5.4	.20
Terramycin Powder	15	5.1	6.4	.25
Carbowax Base	14	7.6	7.7	—
3% Aqueous Hexachlorophene	16	6.5	5.1	−.10

pitalization dictated cessation of the study. In any case where the original method of treatment had to be altered or where systemic medication had to be administered or where observations could not be made to completion of healing, the subject was dropped from the experiment and the data obtained was not included in the final tabulation.

In analyzing the results, the effects of each medication on the various parameters observed was considered. Significant variations are reported in Tables II to VI.

COMMENT

In evaluation of the healing rates of both the experimental and control burns, the figure used was the number of days from the date of induction of the burn to complete healing, using complete epithelialization of the wound surfaces as the criterion of healing.

In evaluation of the intensity of pain, the numerals ("0" to "+4") were weighted, giving an increasing weight to pain recorded later in the course of observation.

For regional adenopathy, the average of all the recorded numbers was taken ("0" to "+4").

The comparison of pain and light touch sensation between normal skin and the burned area were weighted in the same manner as for "intensity of pain".

For evaluation of the quantitative bacteriologic studies, a brush with a fixed number of points was used. The colony counts were given a value of "0" to "+4", depending on the following criteria:

0—No colony growth
+1—Organisms present, but no hemolytic staphylococcus
+2—Single colony of hemolytic staphylococcus, with or without other organisms
+3—Two to five staphylococcus colonies
+4—More than five staphylococcus colonies

In reviewing the data on the effects of the ten test substances on healing rates of the burn wounds, the only significant differences noted were in those wounds treated with vaseline gauze and hexachlorophene, using the customary 5% level of significance.

In an attempt to determine whether there was any difference in healing rates between wounds treated with or without dressings, all control wounds treated with dressings were compared with control wounds of all series treated without dressings, with results as depicted in Table VII.

When the pain index is considered, using an arbitrary index of the number of days, duration of pain post-burn and the intensity of pain ("0" to "+4"), treatment with aluminum powder and hibitane produced less pain than in the corresponding controls.

In considering light touch sensation the results indicate that when significant differences are found in the comparative responses of the burned areas to normal skin, the second degree burn site is always less sensitive than the surrrounding skin.

The only medication which produced an improvement in the degree of regional lymphadenopathy in the treated side appeared to be oxytetracycline powder (See Table IV), and this difference was significant even at the 2.5% level. Vaseline gauze and papain ointment, on the other hand, seemed to cause a sig-

TABLE VII

Comparison Between Controls Treated by Dry Dressings and Open Method

	Open Treatment	Dry Dressing
No. of Trials	58	92
Mean	36.8 days	35.8 days
Standard Deviation	7.2	12.5

The difference of the means is not statistically significant at the 5% level.

nificant increase in the degree of lymphadenopathy on the treated side as compared to the control sides. The other medications produced insignificant differences.

Edema of the burn site, as gauged by the circumference of the limb, seemed to be significantly increased in those burns treated with vaseline gauze and papain ointment, when compared to their corresponding controls. Some of the edema resulting from treatment with papain and chymopapain was probably on the basis of drug sensitivity since almost all burns treated with this substance developed what appeared to be a moderate to severe contact dermatitis at the burn site.

When Rezifilm spray was used, there was an increase in healing time of the experimental burn at the 50%, 75% and 90% point, which was significant at the 1%, 2%, and 5% level respectively. At the 100% healing point, however, there was no significant difference in comparing the control and experimental sides. (See Table II.)

None of the agents used for treatment with the exception of Hibitane ointment produced a significant decrease in the bacteriological index of the experimental wound when compared to the control group. The decrease in bacterial growth noted with hibitane was significant even at the 1% level. It must be stated, however, that this lack of bacterial contamination of the burn wound had no apparent significant effect on the rate of wound healing.

To summarize these results by individual treatment:

Treatment with aluminum powder produced a significant decrease in intensity of pain, but not for any other factor.

Rezifilm produced a significantly greater loss of touch sensation only. In addition, the presence of a plastic coating over the burn site presumably acted as the anterior wall of a closed abscess in those wounds which became infected and had a deleterious effect on the wound by inhibiting drainage.

Treatment with papain provided a significantly greater increase in adenopathy, and also a higher index of swelling than did the corresponding controls.

Hibitane ointment resulted in a significant decrease in pain index, as well as greater loss of pain sensation at the treated sites. This was the only medication which produced a significant decrease in the bacterial growth on the burn wounds.

Vaseline gauze produced a significant decrease in healing time but an increase in adenopathy and swelling.

Carbowax ointment and xylocaine ointment produced no significant alterations at the 5% level in any of the parameters treated.

Oxytetracycline powder produced a significant decrease in adenopathy.

Finally, with hexachlorophene lotion, there was a significant decrease in healing time.

A word may be interjected here concerning the effect of skin pigmentation on burns. Negro skin, when subjected to the same intensity of radiant heat as Caucasion skin, appears to suffer a burn of identical depth. The lag phase appears to be longer in the Negro, which may be due to other factors than pigmentation, but total healing time appears to be the same. In tatooed areas, the initial burn is deeper, again with a prolonged lag period of wound healing, but the experimental wound, in most instances, is completely healed at the same time as its control.

SUMMARY

The need for an objective evaluation of existing methods for local burn therapy has been cited and an experimental program for realizing this goal has been described.

An apparatus which served as a radiant heat source, capable of consistently producing a constant, standard burn in a very short period of time has been designed and constructed to facilitate this experiment.

Ten methods of local burn therapy have been evaluated in one hundred volunteers, each subject serving as his own control.

The preliminary results of this study have been presented.

REFERENCES

1. COMBES, F. C., RESCHKE, M. AND SAPERSTEIN, R. B. Topical anesthesia; effect on tissue regeneration. Am. J. Surg. **74:** 45–48, 1947.
2. HINSHAW, J. R. AND PEARSE, H. E. The effects of some locally applied medications on the healing of second degree burns. UR-518, University of Rochester Atomic Energy Project, pp. 1–14, Feb. 25, 1958.
3. LERMAN, B. AND HINSHAW, J. R. Some attempts to modify the early healing process of moderate second degree burns. UR-537, University of Rochester Atomic Energy Project, pp. 1–14, Jan. 30, 1959.
4. LYON, J. L., DAVIS, T. P. AND PEARSE, H. E. Studies of flash burns: the relation of thermal energy applied and exposure time to burn severity. UR-394, University of Rochester Atomic Energy Project, pp. 1–27, May 24, 1955.
5. MURRAY, J. AND CALMAN, R. M. Control of cross-infection by means of an antiseptic hand cream. Brit. Med. J., **1:** 81–83, 1955.
6. PAYNE, F. W. AND HINSHAW, J. R. Histologic studies of early healing process in moderate second degree burns. UR-514, University of Rochester Atomic Energy Project, pp. 1–41 Feb. 12, 1958.

DISCUSSION

DR. NICHOLAS GIMBEL (Detroit, Michigan): When we sew up a closed wound we know that there are two factors involved. One is the internal debridement and the second is the proliferation. With an open surface wound we have the same two factors that must go on, the cleansing of the surface and then the proliferation of the epithelial elements.

Dr. Sokolic's study is therefore a somewhat complex one, in that there are these two components. It is possible that a treatment which is best from one aspect might not be best from the other. We would expect, let's say, proteolytic enzymes to give the cleanest surface fastest, but they might not be best for the struggling epithelium. Burns of different levels might perhaps give opportunities to study those factors to a different extent.

This burn which requires on the average 35 days to heal is obviously an extremely deep second-degree burn. We ordinarily think of something like ten to twenty-five days to be a fair range for most partial-thickness burns. The greatest changes shown in any of these methods of treatment is a matter of 10 per cent, between 31 and 38 days, in Dr. Sokolic's manuscript. It is interesting that they are also more or less uniform regardless of what is done. It suggests that in some way the experimental situation must be much more important than anything that is done to it, which is, after all, his principal point.

I wonder whether the principal point might not be that there is some evil associated, as we all generally believe, with frequent dressing changes. We all know that if you have healing skin donor sites repeated changing of the bandage is the best way to hinder epithelization. According to the protocol, after the seventh day, these dressings were all changed every second day during this twenty-five-day period, and I would like to ask Dr. Sokolic what the healing times are like, so far as you can tell without looking at it or looking at it at rare intervals, if the regime of frequent dressings is avoided. It is a little like doing a clotting time on a blood specimen. The oftener you tip it the faster it clots, yet if you don't tip it you don't know when it is clotted.

I would like to ask a little bit about the criteria of epithelization. In a study as important as this you wonder whether visual and photographic inspection is always adequate. The criteria as to whether you see a clot present doesn't mean that there may not be healing underneath the clot, as we all see with the open treatment.

I wonder if this really is a fair evaluation of open versus closed treatment for burns. The open treatment as we do it best in the hospital is not done on people who are up and walking around. The cooling in the air is not as good, and of course we all feel that burns of the lower extremities are best treated off their feet anyway because of the dependent factors. While that is true for both methods, it is possible that the mobilization and so on might be more important to the open treatment.

I do approve very much of work on humans because they are so much more human than animals.

DR. IRVIN H. SOKOLIC (Closing) (Philadelphia, Pennsylvania): I would like to thank the discussers, particularly Dr. Gimbel.

You were quite right. Did we redress too frequently? When we originally set up the protocol we didn't know when to start redressing. We arbitrarily chose this particular time because we felt pretty much as you did, that 100 per cent epithelization, which we defined as our healing criteria, would probably occur in two to three weeks. We didn't want to miss whatever factors were going on underneath the dressing, and that's why we chose to redress at the end of seven days. I might also point out that even in the wounds we didn't redress treatment was not particularly effective.

Our criteria of epithelization were not completely adequate. Perhaps we should have biopsied the lesions. But we felt that if we kept going back and rebiopsying lesions we would have the additional problem of the effect of repeat biopsy upon healing rate.

We were not concerned with major burns in this particular instance. We were more concerned with what Grandma does to the little child that sticks his hand on the stove. What should she put on? Usually it is a concoction of 35 different medications. We chose not to use concoctions, primarily because we wouldn't know what would be doing what at any particular time, so that I agree with him that the healing process is an extremely complex one.

I can sum it up at the present time by saying it doesn't make much difference, if any, how a second degree burn is treated. (Applause)

PREVENTION AND TREATMENT OF SKIING INJURIES

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Ski injuries are athletic injuries. As such, they are characterized by the fact that they are produced by circumstances inherent in the athletic performance, and the patients are, therefore, exposed to recurrent identical trauma and strain, making re-injury likely.

Skiers are, furthermore, unusual because they are the largest group of non-athletes engaging in athletic activity. The average skier is sedentary throughout the year, and then exposes his limbs without preparation to the sometimes extreme strains and efforts of the sport. If he has suffered injury, his daily activities do not suffice to restore function of the injured part anywhere near the level required for safe use in the sport.

The most important single prevention of ski injury, therefore, lies in proper conditioning, adapting the body to the physical requirements of skiing (Fig. 1) (7, 13, 14, 15, 22).

While progress has been made in providing safer equipment (release bindings), and more skiers go to ski school thus improving their skill, the use of reconditioning as a preventive measure has only been started.

It used to be that the injured skier came in with the question "Can I ski again?" Now even the more severely injured skier comes with the question "When can I ski again?" Thus management of ski injuries which, of course, basically rests on generally accepted orthopedic principles, is given the special added problem to restore full function in the shortest possible time.

The goal of early and complete restoration of function can best be reached by planning from the very first day of injury. With this in mind immediate mobilization is often used where rest and immobilization were used before (1, 7, 8, 10).

The obstacles to immediate mobilization of injury are pain and muscle spasm which are aggravated by motion. Since we have learned to overcome these symptoms, immediate active motion is feasible in a great number of injuries (Fig. 2) (5, 8, 16, 17, 9).

Immediate mobilization not only shortens recovery considerably but holds loss of muscle strength and flexibility to a minimum thus making complete restoration easier. Results of a twenty year study of injury to ligamentous apparatus of the knee joint may illustrate this point (Fig. 3) (7, 10, 11).

Wherever major tear of ligaments exists, surgery is indicated. Overlooking such tears and classifying them as sprains is responsible for many cases of "chronic" sprain. On the other hand, rest or immobilization without subsequent complete restoration of muscle function is equally responsible for the dictum "Once a sprain—always a sprain".

The technique of immediate mobilization after injury rests on relief of muscle

PRE-SKI CONDITIONING RESULTS IN FEWER INJURIES

	SKIERS	DAYS	FRACTURES
SKI CLUB	COND.	5,000	0
WESTCH.	NON-COND.	500	3
NORTH		HOURS	
COUNTRY	COND.*	5,000	0
SCHOOL	NON-COND.	5,000	7

*2 CHILDREN DID NOT PARTICIPATE - BOTH FRACTURES
(B. Prudden, White Plains
North Country School, Lake Placid)

FIG. 1

IMMEDIATE MOBILIZATION MAY BE USED FOR:

SPRAINS: ANKLE, KNEE
STRAINS: LOW BACK, CALF, HAMSTRINGS
FRACTURES: THORACIC & LUMBAR SPINE
PELVIS (OS PUBIS)
"INTRABOOT" FRACTURES
TIP, EXT. MALLEOLUS
HEAD OF HUMERUS, IMP.
METACARPALS

FIG. 2

FIG. 1. (After Kraus, H. Prevention and Treatment of Ski Injuries. J.A.M.A. **169**: 1414–1419, Mar. 1959.)

FIG. 2. (After Kraus, H. and Mahoney, J. W. Fracture rehabilitation. Covalt A. D., Rehabilitation in Industry, pp. 33–36, Grune & Stratton, New York, 1958.)

Reconditioning Prevents Re-injury

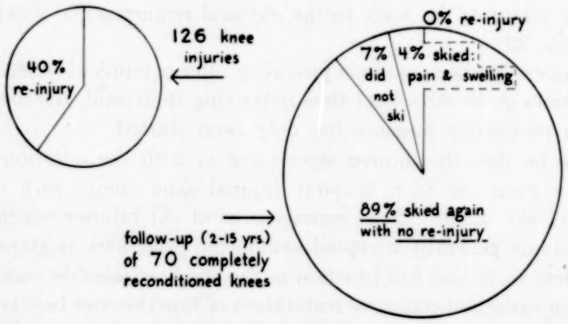

FIG. 3. (After Kraus, H., Mahoney, J. and Weber, S. Immediate mobilization of certain ligamentous injuries of the knee. G.P. (in publication).)

spasm, on use of pain relieving agent and immediate gentle limbering motion. We have been using ethyl chloride spray successfully for almost thirty years (9, 18, 19, 20, 21). Other physical means to break muscle spasm include novocaine iontophoresis, use of tetanizing and sinusoidal currents, and hot packs.

Ethyl chloride spray has the advantage of great effectiveness and easy application.

(Fig. 4) The pain is located by active motion. Ethyl chloride is then sprayed on this area. The patient then starts active movement of the part involved, in the direction in which motion has been painful and limited. As the patient increases his range, new painful areas will develop. These areas must again be sprayed, and active motion continued. Treatments last from 10–30 minutes, and should be carried out within limits of pain.

Immediate use of the affected part may be allowed in patients able to perform

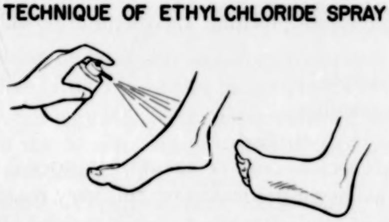

Fig. 4. (After Kraus, H. Evaluation and treatment of muscle function in athletic injury. Am. J. Surg., **98:** 353–362, 1959.)

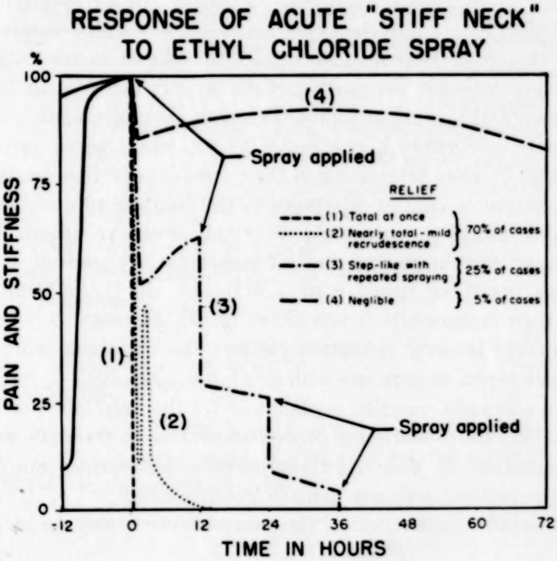

Fig. 5. Response of acute "stiff neck" to Ethyl Chloride spray. (Reproduced from Travell with permission of Arch. Phys. Med. & Rehab.)

normal movement, but excessive strain and sudden movement should be prohibited. Patients with more severe disabilities should be advised to rest, but all patients should be urged to continue the active movements that they have been taught. The exercises should be performed from a minimum of twice a day to as often as once every hour, for approximately five minutes. While a single treatment will suffice in cases of minor involvement, patients with more serious difficulty require frequent treatment: Daily during the first week and later every other day.

Ethyl chloride spray reduces pain and spasm considerably at subsequent sessions (Fig. 5) (20). The acute pain should subside within 4–6 days but ethyl chloride spray will continue to be useful to increase function by exercises by raising rather than overstepping the pain threshold.

Compared with injection of procaine, the use of ethyl chloride spray has definite advantages:

(1) Application is simple,
(2) repeated use is possible,
(3) large areas can be controlled,
(4) it does not mask serious bone or ligament injuries,
(5) it can be used as diagnostic means for this very reason,
(6) there is less risk of local after-effect and no general after-effect, and
(7) there is no danger of infection.

The administration of surface anesthesia is only one part of the treatment. Combination with exercises is a MUST. Without it, the use of surface anesthesia would accomplish little more than the use of gas in surgery without operation.

As to the theory of the effect of surface anesthesia in the relief of muscle spasm: Pain originating in one portion of the sensory motor chain leads to reflex muscular spasm and locking of joints. This sensory motor chain consists of the following elements: Sensory nerve, nerve center, motor nerve, muscle and sensory nerve (Fig. 6). Pain originating in the course of this chain leads to muscular spasm. Elimination of pain at any point in the chain results in the breaking of the chain, and, therefore, in relaxation of the muscular spasm. This may be achieved directly by the injection of an anesthetic into the muscle, joint ligament, sensory nerve, or spinal cord. Cutaneous anesthesia similarly relieves deep-seated pain in muscular spasm (8, 9, 12, 20, 21).

If the pain-free interval is used to restore the muscle to normal function, spasm does not recur, or it recurs with much less intensity.

There is no adequate scientific explanation for the deep effect of surface anesthesia. However, the underlying physiological reason presents an interesting field for exploration. It should be emphasized that surface anesthesia alone, without active motion, will not achieve good results.

Manual resistance/assistance is the most effective way to strengthen and

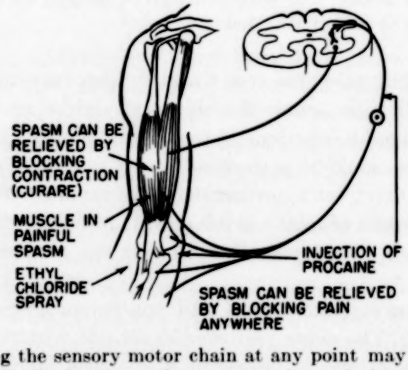
SPASM CAN BE RELIEVED BY BLOCKING CONTRACTION (CURARE)
MUSCLE IN PAINFUL SPASM
ETHYL CHLORIDE SPRAY
INJECTION OF PROCAINE
SPASM CAN BE RELIEVED BY BLOCKING PAIN ANYWHERE

FIG. 6. Interrupting the sensory motor chain at any point may help to relieve muscle spasm. (After Kraus, H. Evaluation and treatment of muscle function in athletic injury. Am. J. Surg., **98:** 353–362, 1959.)

limber muscles since the skilled person is able to give just as much resistance and gentle stretch as can be favorably absorbed by muscles (Fig. 7).

When the acute phase is over, exercises have to be increased steadily following the overload principle. The overload principle states that strength of a muscle can only be gained if the demand exceeds present easy performance. The same applies to flexibility of a muscle (8, 2, 3, 4).

Immediate mobilization does not mean immediate weight-bearing. Even if the bone is ready for it, premature weight-bearing will force the patient to substitute muscle groups, will prolong limping, pain and disability.

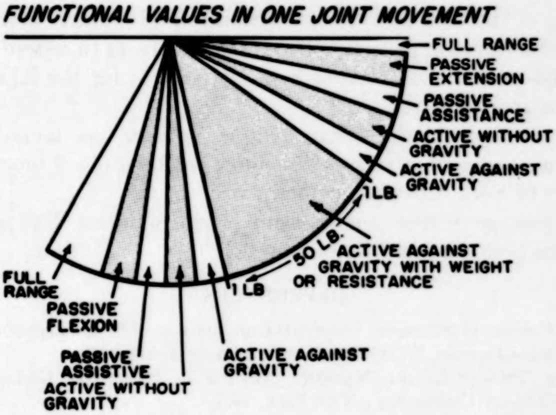
FUNCTIONAL VALUES IN ONE JOINT MOVEMENT
FULL RANGE
PASSIVE EXTENSION
PASSIVE ASSISTANCE
ACTIVE WITHOUT GRAVITY
ACTIVE AGAINST GRAVITY
1 LB.
50 LB.
ACTIVE AGAINST GRAVITY WITH WEIGHT OR RESISTANCE
1 LB
FULL RANGE
PASSIVE FLEXION
PASSIVE ASSISTIVE
ACTIVE WITHOUT GRAVITY
ACTIVE AGAINST GRAVITY

FIG. 7. Manual resistance exercises can adjust to the varying strength and flexibility throughout the joint range. (After Kraus, H. *Principles and Practice of Therapeutic Exercises*, Charles C. Thomas, Springfield, Ill., 1956.)

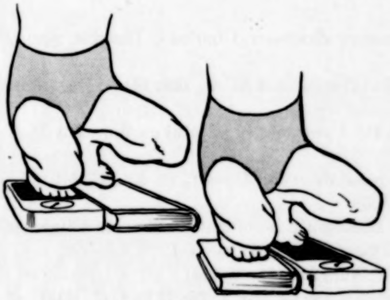

FIG. 8

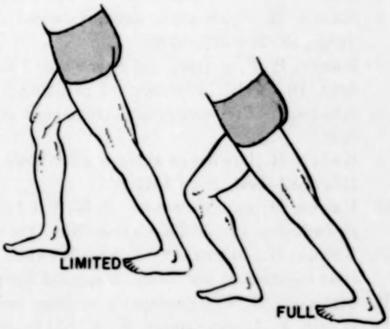
LIMITED
FULL

FIG. 9

FIG. 8. Scale test to gauge strength of injured extremity. (After Kraus, H. Evaluation and treatment of muscle function in athletic injury. Am. J. Surg., **98:** 353–362, 1959.)

FIG. 9. Testing of flexibility, length of soleus muscle of right foot. (After Kraus, H. Evaluation and treatment of muscle function in athletic injury. Am. J. Surg., **98:** 353–362, 1959.)

Whether the patient is ready for skiing depends not only on sufficient healing of bone and ligament but equally on restoration of muscle function. Muscle evaluation for strength (Fig. 8) and flexibility (Fig. 9) are essential before declaring the patient fit for the sport. Only if the extremity is as strong as the contralateral side can this be permitted safely (6, 7).

The mere passage of time is no measure of rehabilitation. Full restoration of function is the best safeguard for re-injury.

SUMMARY

Poor muscular condition is a main cause for ski injury. Physical conditioning before skiing is the best prevention. Weakness and stiffness after injury are among the main causes of re-injury. Therapeutic exercises to restore full function of the injured part are essential to make it possible for the injured skier to return to his sport safely.

The use of ethyl chloride spray and active exercises immediately after sprains, strains and certain types of fractures has been found most effective in over 25 years of work with that method.

The mere passage of time is no measure of rehabilitation. Full restoration of function is the best safeguard for re-injury.

REFERENCES

1. American College of Surgeons. Committee on Trauma. *The Management of Fractures and Soft Tissue Injuries*, W. B. Saunders Co., Philadelphia, 1960.
2. De Lorme, Thomas L. and Watkins, Arthur L. *Progressive Resistance Exercise*, Appleton-Century-Crofts, Inc., New York, 1951.
3. De Lorme, T. L. and Watkins, A. L. Technics of progressive resistance exercise. Arch. Phys. Med., **29:** 263–273, May 1948.
4. Hellebrant, F. A. Recent advances in methods of hastening convalescence through exercise. South. M. J., **39:** 397–401, 1946.
5. Kraus, H. New treatment for injured joints. J.A.M.A., **104:** 1261, Apr. 1935.
6. Kraus, H. Evaluation and treatment of muscle function in athletic injury. Am. J. Surg., **98:** 353–362, 1959.
7. Kraus, H. *Principles and Practice of Therapeutic Exercises*. Charles C Thomas, Springfield, Ill., Publ., 1949/50, 3rd printing.
8. Kraus, H. Prevention and treatment of ski injuries. J.A.M.A., **169:** 1414–1419, March 1959.
9. Kraus, H. The use of surface anesthesia in the treatment of painful motion. J.A.M.A., **116:** 2582–2583, June 1941.
10. Kraus, H. and Mahoney, J. W. Fracture rehabilitation. Covalt, D. A. *Rehabilitation in Industry*, pp. 33–36, Grune, New York, 1958.
11. Kraus, H., Mahoney, J., and Weber, S. Immediate mobilization of certain ligamentous injuries of the knee. Accepted for publication in 1961 by G. P.
12. Melzack, R. The perception of pain. Scient. Am., **204:** 41–49, 1961.
13. Rigos, F. J. and Gross, K. E. Ski injuries. Northwest., Med. **56:** 1315–1317, 1957; abstracted J.A.M.A., **166:** 972–973, 1958.
14. Smith, V. D. E. Ski injuries—their prevention. Bull. Am. Coll. Surgeons, **40:** 289–290; 457–459, 1955.
15. Springer-Miller, F. Accident Statistics 1956/57, Stowe, Vt., Report to Northwestern Medical Association. Feb. 1958.

16. Travell, J. Management of pain due to muscle spasm, in Conference on Therapy' New York J. Med., **45:** 2095–2096, 1945.

17. Travell, J. Treatment of painful disorders of skeletal muscle, in Conference on Therapy. New York J. Med., **48:** 2050–2059, 1948.

18. Travell, J. Basis for multiple uses of local block of somatic trigger areas (procaine infiltration and ethyl chloride spray). Mississippi Valley M. J., **71:** 13–21, 1949.

19. Travell, J. Ethyl chloride spray for painful muscle spasm. Arch. Phys. Med., **33:** 291–298, May 1952.

20. Travell, J. Relief of pain by ethyl chloride spray, in Cornell Conference on Therapy. New York J. Med., **52:** 1550–1558, 1952.

21. Travell, J. and Rinzler, S. H. The myofascial genesis of pain. Postgrad. Med., **11:** 425–434, 1952.

22. Woodard, Christopher. *Sports Injuries.* Max Parrish, London, 1954.

LATE PROBLEMS ASSOCIATED WITH DELAYED HEALING OF BURNED PATIENTS

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The requisites for success in the care of the extensively burned patient have been translated into practical principles as a result of much important information gained during the last 25 years. Modern refinements in the application of fluid therapy and antibiotics have decreased the mortality in moderate burns and prolonged the survival time in extensive burns. As Artz and Reiss (2) have pointed out, these developments have created new problems, since patients who formerly died from fluid deficits now live long enough that their survival is threatened by other factors. It also seems apparent that the morbidity among surviving burn patients continues to vary between wide extremes, depending upon the degree of interest and proficiency in burn technics among surgeons. Consequently, we are now seeing an increasing number of severely debilitated burned patients who maintain a state of tenuous survival for months after injury, while open wounds are allowed to persist with little or no coverage having been achieved.

The early treatment of extensive burns, although simple to describe in terms of principles is so difficult and complex in practice that one can rarely be factually and justifiably critical of the management of patients with major burns who survive. Yet the almost insurmountable difficulties to be encountered in the late treatment of debilitated non-healing burned patients strongly motivate the surgeon who is faced with the problem to seek a means of preventing this graft-refractory state.

The mechanisms of recovery from severe thermal injury are possibly even more complex and problematical than the body of literature which embraces the subject. The established principles of therapy, the major contributions in the field, and the pathogenesis of complications to be avoided, have been admirably documented recently by Artz and Reiss (2). It is because of the previously mentioned increase in the number of debilitated patients from the "elsewhere" hospital that we report on this group of patients. The problems they represent, we believe, are in some measure, products of the medical profession, created through the medium of missed or unrecognized opportunity for early definitive therapy. It is our purpose to re-emphasize the principles and practices by which

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some of these problems may be avoided, and to outline points in the management of such refractory patients which we have found practical in our hospital.

Within a two-year period since 1957 five patients with extensive unhealed full-thickness burn wounds have been referred to the Highland View Cuyahoga County Hospital, from other hospitals in the Cleveland area, after intervals of one month to one year following injury. As judged by records, these patients received adequate initial replacement therapy, antibiotics, and in most instances some skin grafting within three weeks after injury. All had received blood transfusions for anemia, and the physical state of their wounds at the time of transfer indicated no extreme neglect of dressing changes. Notes from the records indicated that much time and labor had been expended in the care of these patients and that the physicians in charge were knowledgeable and conversant with the accepted principles of burn therapy. Yet these patients had languished for prolonged periods in states of progressive depletion while developing joint deformities and losing their will to live. As a group, these patients were psychologically and physiologically exhausted to the point of chronic anxiety and belligerent inertia. They exhibited anorexia, anemia, hypoproteinemia, extreme weight loss, and a dislike for physical activity in any form. Some had developed pressure ulcers and all resisted dressing changes or even minor manipulations without benefit of narcotics or anesthesia. Summaries of the clinical courses of these patients are given below.

Case 1

Admitted August 21, 1958. This twenty-one year old white female sustained 2nd and 3rd degree burns over trunk, arms, face and neck described as approximately 45% of body surface February 14, 1958, when a gas main exploded under her home. She was hospitalized at another institution for six months, during which time she received an unknown number of blood transfusions, underwent six episodes of grafting to face, neck and arms only. Grafts were stated to have all been successful, but delay in further grafting was imposed because donor sites did not heal as nutritional decline with anorexia persisted without remission. The patient was transferred after six months to Highland View Hospital with persisting 3rd degree wounds over shoulders, trunk and arms. (See Figures 1 and 2.) This patient's weight changes and other data are depicted in a chart of her progress (Fig. 3).

Treatment consisted of dressing changes in the operating room every day prior to the first surgical procedure, serial blood transfusions, high carbohydrate, high protein diet with supplementary feedings before burned wounds were debrided on 10-1-58 and grafts were applied to back and chest from legs two days later. She had received 4500 ml. of whole blood, dietary intake had markedly improved and steady weight gain had ensued. There was initial 70% success, but grafts over the back disintegrated due to the effect of infection and pressure as patient again became immobile following surgery, although she had become partially ambulatory before grafting.

From November 1958 through April 1959 the patient underwent seven episodes

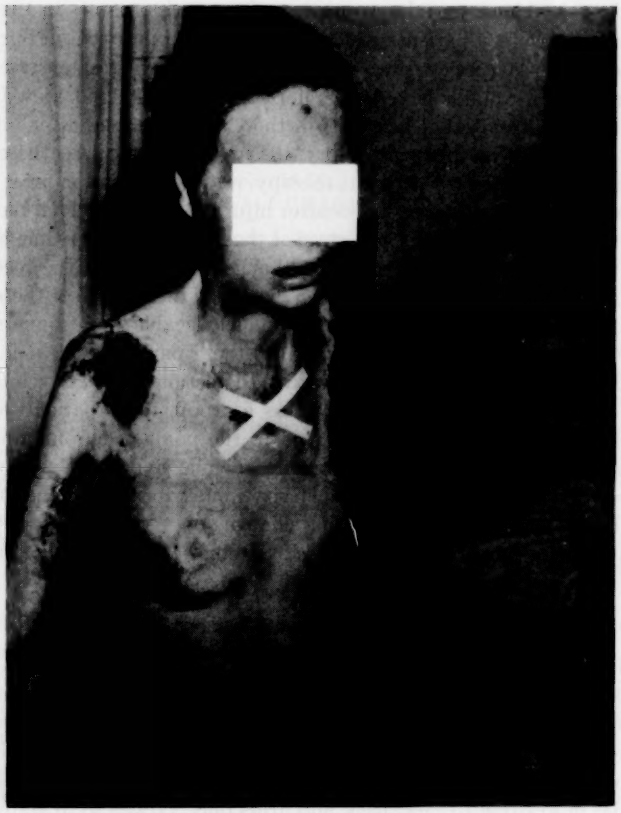

FIG. 1. Case 1. J. M.—View of unhealed deep wounds of upper body, on admission to H.V.H. six months after injury.

of grafting from the thighs and legs to back and chest before wounds were finally healed. Most of the grafting episodes were initially successful but skin was subsequently lost due to infection and inability to avoid pressure over the back. Two sets of grafts were lost with staphylococcal infection, while two episodes of failure occurred when pseudomonas was the dominant organism in the wound area. Success was finally achieved after we began resorting to daily detergent baths with dressing changes and topical antibiotics.

The patient's hands were badly deformed upon arrival at this hospital. Metacarpo-phalangeal joints were fixed in extension and phalangeal joints were frozen in most fingers. (Fig. 4.) This appeared to be due to early malpositioning and skin deficit over dorsal aspect of hands. It was decided to delay definitive capsulectomy and fixation of joints for several months after final skin grafting, since hand motion continued to slowly improve and irreversible changes had already

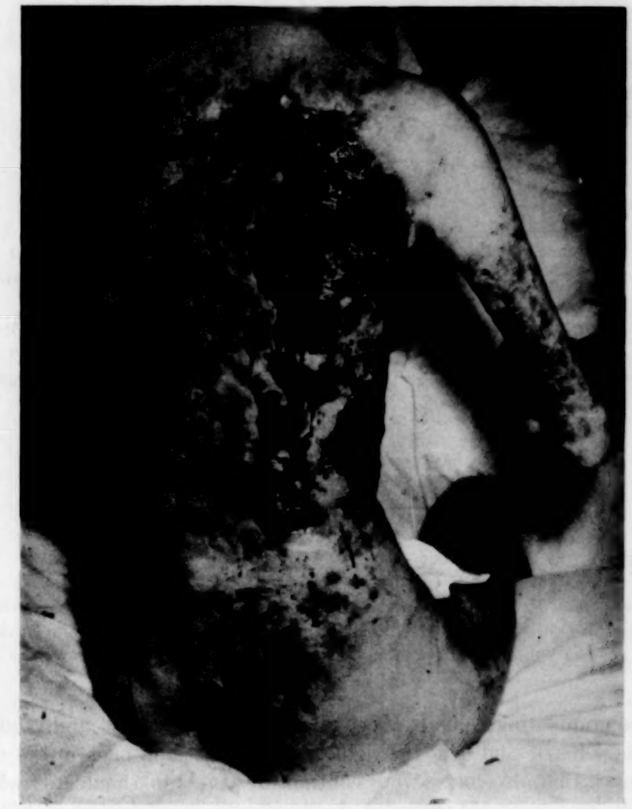

FIG. 2. Case 1. J. M.—View of back on admission showing extensive full thickness defects and marked loss of blood during a dressing change.

been long established. Further plastic surgery is contemplated for face, neck and axillae. Figures 5 and 6 show condition of patient at time of discharge ten months after admission.

Case 2

The patient was a sixty-two year old white female who was admitted to Highland View Hospital on January 7, 1957. In February 1956 she had sustained extensive burns of second and third degree, estimated to cover 60% of the body surface. During the twelve months prior to her referral to Highland View Hospital she was treated in another institution, during which time she received eight blood transfusions, was skin grafted nine times, and otherwise treated with supportive care and dressing changes. At the time of her transfer she was bedridden and unable to care for herself, she had unhealed donor sites over both thighs, there

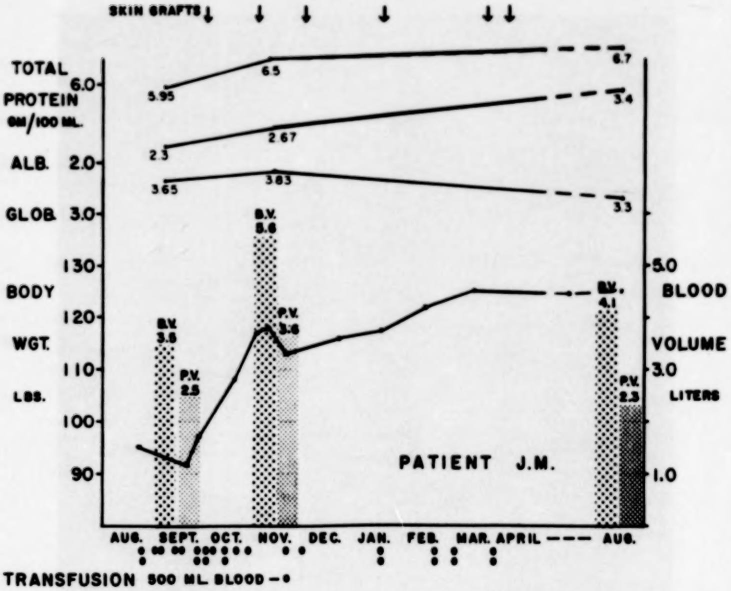

Fig. 3. Case 1. J. M.—Graphic summary showing nutritional improvement during period of hospital stay. Note body weight gain and serial transfusions prior to initial skin graft. Blood and plasma volume changes, along with serum protein concentrations are depicted.

were large granulating wounds over the right lower abdomen and groin, under both axillary fossae and over the right anterior chest and back in the region of the scapulae. She also had severe contractures of both shoulders and elbows limiting the motion to 45° extension in elbows and 30° abduction in both shoulders. The granulations covering all wounds were pale and edematous and covered with a necrotic exudate of a very thin mucoid character.

The two problems immediately dealt with in this patient were her undernutrition and anemia and superficial infection in the burned areas. She was given a high protein, high caloric diet and the burned areas were managed by dressing changes twice daily after soaking thirty minutes in the Hubbard tank. Physical therapy of contractures was carried out during these periods in the tank. She was given serial whole blood transfusions, during which time the granulation tissues remained quite edematous and wounds were debrided from the anterior chest and arms, and skin grafts applied. Wet saline dressings were applied postoperatively. The first grafting proved to be approximately 80% successful, and after three weeks more skin grafts were applied to the upper back after granulations were debrided. Hubbard tank treatments were resumed approximately one week after each grafting episode and the wounds progressively healed at a very slow rate. A final grafting procedure was carried out three months after her admission at which time small split grafts were placed over the anterior

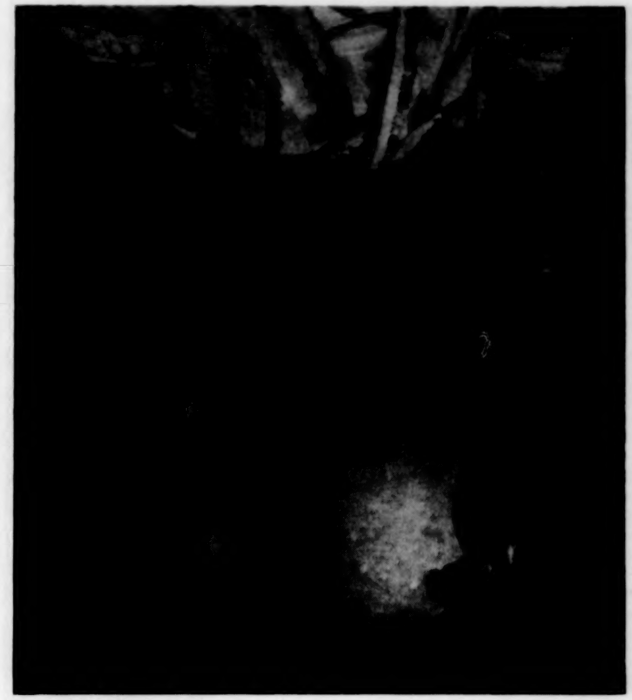

FIG. 4. Case 1. J. M.—Appearance of hands on admission showing extensive deformity of the metacarpo-phalangeal and distal joints.

chest. The patient was discharged from this hospital three and one-half months after admission with all granulating wounds finally closed.

The patient was readmitted to Highland View Hospital July 22, 1957, for treatment of contractures of the right and left elbows and right axilla. She had been able to conduct the usual household activities during the period at home. On August 6, 1957, a split thickness graft was placed on the left ante-cubital fossa following resection of scar tissue. On August 14, 1957 split thickness grafts of the right arm and ante-cubital fossa were applied after which a full range of motion of both elbows was possible and satisfactory range of motion of the left shoulder had developed. This occurred concomitantly with release of scar tissue at the left elbow; however the right shoulder did not respond in like manner and responded only moderately to subsequent exercise programs. The patient was discharged for the second time from this hospital on September 5, 1957, with burned areas intact.

Case 3

This fifty-year old negro male was admitted to Highland View Hospital March 5, 1958, from another hospital. Six months previously he had been in-

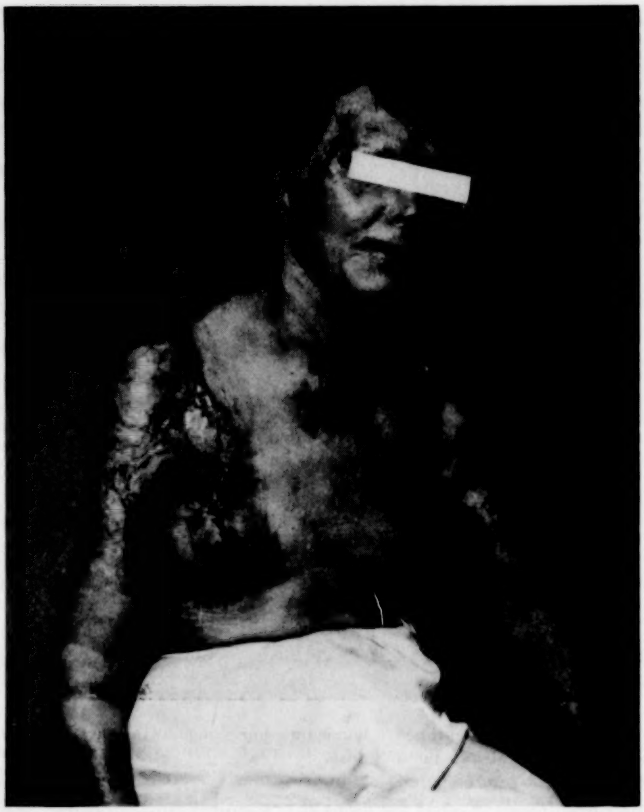

FIG. 5. Case 1. J. M.—Appearance of upper body at time of discharge.

volved in a gasoline fire which had burned the clothing from the lower half of his body and resulted in second and third degree burns of the lower extremities. He was transferred to this hospital with large persisting defects over the thighs and legs, although he had been grafted twice during the first three months after injury. According to the history, his failure to heal was due to infection which was treated with penicillin and his course then became complicated by an allergic response to this drug. Aside from the skin defects due to burns, the patient also had an incipient 45° contracture of the right knee, secondary to wounds in the popliteal space. The patient was admitted to this hospital with a hematocrit of 41% and Hb. 12.3 gms. and a white count of 9,850. His total serum proteins were 7.9 gm./100 ml. with 3.3 gm. albumin.

This patient had received blood transfusions at the other hospital and his general condition was better than that of most patients of this type that we received. Previous grafts applied to the lower extremities had been partially

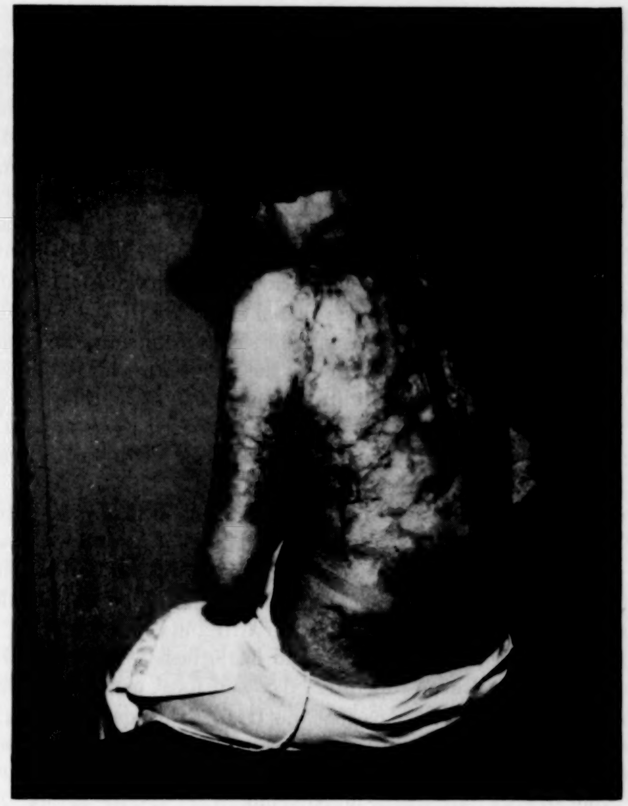

FIG. 6. Case 1. J. M.—Appearance of back showing complete wound coverage at time of discharge.

successful and therefore his defects were irregular and of varying depth. Five days after admission grafts were taken from the back and applied in strips and stamps to the lower extremities and plaster splints were applied to the legs. On the third postoperative day the patient sustained a pulmonary embolus for which he was anticoagulated with Heparin without recurrence of this problem. Approximately 75% of the grafts survived and after ten days more grafts were applied to the extremities from the back. One month after admission all defects were essentially healed, although both knees presented flexion contractures of 5°. After being placed on an ambulation program he had progressed rapidly to independent walking and stair climbing. The patient was discharged home after five weeks.

Case 4

Admitted August 21, 1958. A fifty-year old white female, mother of Case 1, was admitted with second and third degree burns of the right arm, right thigh, face and ears, sustained when a gas main exploded under her home on the 14th of February, 1958. The patient's injuries were cared for in another hospital for the first six months, during which time the burns of the face and most of the abdomen healed spontaneously, while the right lower extremity had been grafted on April 14, April 25, May 19 and July 3, 1958. She was said to have received repeated blood transfusions; however her wounds were extremely slow to heal. At the time of her arrival here there were open granulating wounds over the right upper arm and smaller sites over the abdomen, said to have been donor sites which failed to heal. The major area devoid of skin comprised most of the right lower extremity which exhibited scattered epithelial islands surrounded by old fibrotic granulation tissue. The original area of burn was estimated to be around 20% of the body surface. This patient's emotional status was quite labile and she was highly resistant to suggestion or the slightest modification in management. There was an equinus contracture of the right foot and the right knee was resistant to extension beyond 165°. The patient's hearing was impaired to the degree that she could only understand the shouted voice with the use of a hearing aid.

Upon her arrival the patient began a daily routine of detergent baths in the Hubbard tank, followed by application of dressings. The patient was maintained on a high protein, high carbohydrate, high vitamin diet and after being given three units of whole blood by September 10, 1958, split grafts from the left thigh to the right arm, abdomen and right lower extremity were applied. Prior to grafting the wound beds were debrided and hemostasis was secured. Dressings were removed on the fifth postoperative day and most of the grafts had been destroyed by infection. After the patient was treated with daily dressing changes for one week, the Hubbard tank baths were resumed. The large granulating areas over the right lower extremity persisted while the patient obstinately refused further surgery, but finally, on November 12, 1958, the patient permitted application of split thickness grafts to abdomen and both thighs from the left thigh. Approximately 70% success was attained with this grafting procedure and after two weeks the Hubbard tank baths were resumed. Although multiple small lesions up to 3 cm. in diameter persisted over the right lower extremity and the abdomen, the patient steadfastly refused to submit to further grafting, and slowly healed by scarring over a period of three months. At the time of her discharge home, the granulating areas were diminished in size but many were still unhealed and the quality of skin over much of her right lower extremity indicated that it might not remain intact with the dependency of walking and standing. Such proved to be the case, since at follow-up one year later there were still open ulcerations over the left arm and right leg. There is a persistent contracture in the right popliteal space which has been restricted in development to some degree by stretching and exercise. The patient still refuses corrective surgery.

This patient demonstrates the results of excessive scarring and extreme delay in healing of the lower extremities in the elderly burned patient. The poorly nourished epithelial covering is extremely sensitive to trauma and subject to recurrent ulcerations.

Case 5

This patient was a thirty-one year old colored female admitted to Highland View Hospital March 18, 1958, from another hospital. On February 17, 1958, she had sustained first, second, and third degree burns to an estimated 30% of her body. Her treatment had consisted of dressing changes, whirlpool baths, antibiotics and intravenous fluids. No skin grafting had been done. There were denuded raw weeping areas over the right arm, shoulder, abdomen and both thighs, a decubitus ulcer over the sacrum and partially healed burn wounds over the left shoulder and left leg. A contracture of the right elbow limited extension to 60°. After two weeks of intensive wound care, involving dressing changes every other day under anesthesia, several blood transfusions, and special attention to nutrition, the patient had split thickness grafts from the back applied to the right upper extremity and both thighs. After ten days the grafts were 90% intact and donor sites were clean. Two weeks later additional grafts were placed on remaining wounds over both thighs and the right arm. One week following this procedure a deep abscess in the right breast was drained by incision. Wounds remained indolent during this period and grafts were lost over the right thigh. The breast abscess continued to drain for two weeks and underwent very slow resolution. At this time the left thigh and right arm were regrafted and 75% success was achieved. At the end of the second month at this hospital all burned areas were essentially healed. The problems of limitation of right shoulder and elbow motion and limitation of interphalangeal joints of the left hand remained to be subject to continued physical therapy. At the time of her discharge the patient was still making some gains, but need for additional surgery was anticipated.

DISCUSSION

It seems likely that the initial program of management to which all these patients were subjected was acceptable. To pick a specific point of departure from prudent therapy in each instance is difficult, yet the fact that complete skin coverage was ultimately attainable, clearly supports the contention that the same goal might have been reached by simpler means at the beginning. What, then, is the sequence of "minor mistakes" leading to this refractory state of the burned patient? It seems evident that the greatest single error committed in the management of these patients, was undue delay before grafting.

The reasons indicated for delay were varied but usually bore some reference to unsatisfactory appearance of the recipient wound or inadequacy of donor sites. The generally accepted sequence of regional priority was followed in most instances with hands, face, and areas of motion being grafted first (2). In other body regions, however, during the early post-burn period, granulating areas which were surrounded by larger zones of deeper injury still bearing eschar, were often grafted. Dressings placed in continuity then covered all wounds for a period greater than a week without change. When subsequently inspected, the areas of undebrided full thickness injury were providing a common field of suppuration for the entire wound area and the percentage of graft survival was understandably disappointing. A common error in the management of these patients would therefore appear to be failure on the part of the physician to deal aggressively with full thickness burn wounds prior to the stage of frank suppuration.

As has been so appropriately stated by Whalen (23), the third degree burn represents an irreparable loss of an important organ, which must be replaced surgically. Reluctance or undue delay on the part of the surgeon to adopt this viewpoint is inevitably a cause for regret.

Full thickness necrosis of skin characteristically imposes a high degree of susceptibility to local infection against which the effect of antibiotics is only transient and partial at best (4, 17). The element of delay required for spontaneous separation of eschar affords the opportunity for infection to advance under cover. It has been well emphasized by Langohr, Owen and Cope (17) that such wounds become a quagmire of infection after the third week postburn. This period of delay also constitutes for many patients a dangerous interval of nutritional dependency, and they may fare poorly in the hands of the disinterested or detached surgeon. Progressive scarring beneath infected granulation tissue ultimately results in diminished vascularity of the areas to be grafted (16). Beyond a certain period after burn injury, the later grafts are applied, the less receptive is the wound and the greater the rate of graft failure (2).

The second most recurrent feature in the earlier management of this group of patients might be termed the premature therapeutic withdrawal and may be described as follows. The extensively burned patient is provided with appropriate replacement therapy, is grafted at the optimal time, and is maintained according to sound medical principles by an enthusiastic and energetic treatment team to the point where a seemingly certain mortality has been averted. His wounds have been brought to the point of eighty-five to ninety per cent closure with grafts. With a sigh of relief, and professional pride, the patient is then graduated to the do-it-yourself class by the medical staff. Occasionally this patient cannot complete his recovery without further supervision. His state of nutrition is still not self-sustaining and his wounds, while scattered and seemingly small, constitute a relatively large draining area, when viewed collectively and metabolically. His multiple small wounds may continue to "granulate nicely" for a time and indicate promise of early spontaneous closure.

There is usually a lapse in dressing care and wound hygiene during this period and after some weeks of granulating, scarring, and marginal epithelial growth, infection joins with malnutrition to erase much hard won progress. The more thinly grafted and heavily scarred areas adjacent to small chronic ulcers break down and now large confluent defects appear. At this point there may be reawakened interest and concern on the part of the staff. Better wound technic is re-instituted for several days after which the "cleaned up" wounds are regrafted. This round of grafts fails and so does the next until finally the patient and physicians compromise on a therapeutic stalemate consisting of dressing changes by the clock and the indefinite period of waiting for some miraculous change in the wound appearance which might encourage another effort. This vicious cycle is diagramatically presented in Figure 7.

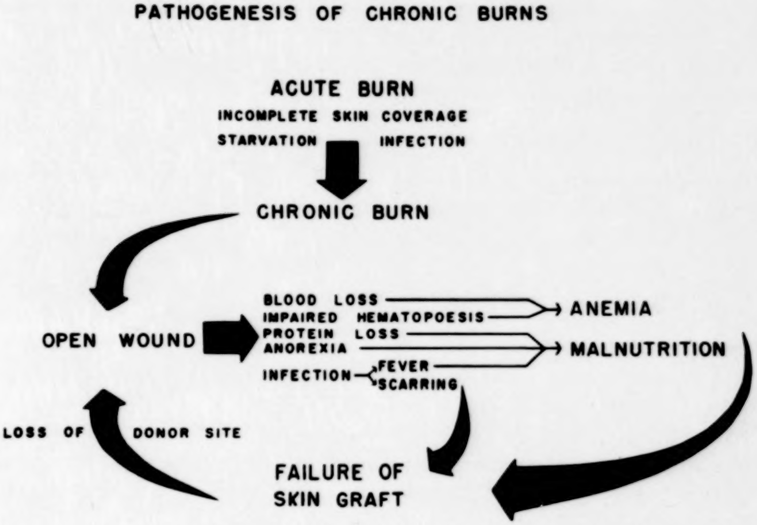
PATHOGENESIS OF CHRONIC BURNS
ACUTE BURN
INCOMPLETE SKIN COVERAGE
STARVATION
INFECTION
CHRONIC BURN
OPEN WOUND
BLOOD LOSS
IMPAIRED HEMATOPOESIS
PROTEIN LOSS
ANOREXIA
INFECTION
FEVER
SCARRING
ANEMIA
MALNUTRITION
LOSS OF DONOR SITE
FAILURE OF SKIN GRAFT

FIG. 7. Graphic summary of pathogenesis of chronic burns.

We believe the two features which must be dealt with initially in the chronic burn are (1) nutritional restoration and (2) control of wound infection. The nutritional problem takes precedence. A sustained effort is mandatory if one is to reverse the changes of chronic starvation. This objective is pursued with simultaneous effort to stay the progress of wound infection until definitive surgery can be undertaken.

METABOLIC ALTERATIONS

The metabolic alterations in the chronic burn patient differ in many important respects from those in the recently burned patient. In the acute post-burn phase the degree of negative nitrogen balance is roughly proportional to the severity of the burn. It may be modified somewhat by dietary pattern, but reversal to a positive balance is usually impossible within less than thirty days after any significant burn. This sustained period of metabolic disequilibrium is usually reflected by a precipitous body weight decline often exceeding a net daily average of one pound. Serum protein levels become altered with a decrease in albumin and elevation of globulins, principally in the gamma fraction (3, 18). The early protein abnormalities are consequences of extensive tissue catabolism. urinary losses and wound exudate composition. As much as 49 gms. of protein per day may be lost in exudate from early wounds (8, 12). These substantial losses of protein are decreased as wound closure is achieved and protein repletion persists for a period of months resulting in a total nitrogen consumption which far outweighs all measured losses. Many patients with burns of moderate extent may heal without special attention to protein repletion.

Cope, et al. (9) were among the first to demonstrate that the basal metabolic rate remains elevated until wound healing is almost complete. This increase in the body's energy requirement is reflected in an acute and severe metabolism of body fat, which occurs despite nutritional therapy and persists after nitrogen balance becomes positive. There is also an acute disturbance of carbohydrate metabolism similar to that found with surgery and which is of relatively brief duration.

The electrolyte abnormalities associated with an acute burn may be quite severe but with proper therapy are brought within a compensated range after 48 to 72 hours and do not generally constitute a long-standing physiological problem. There is a chronic urinary loss of potassium which may persist despite therapy. Impaired hematopoesis following an acute burn has been pointed out by James (15) as a companion cause of anemia along with that of acute thermal injury to erythrocytes.

Our concept of the metabolic alterations of the depleted post-burn state is that it represents adaptation to chronic starvation. Nitrogen balance approaches equilibrium, albeit at a very low quantitative level. The concentrations of albumin and globulin are usually reduced and the total circulating plasma proteins reflect the hypovolemia of the starved state. The severity of this depletion may be illustrated by Case 1, (Figure 3) who had a total circulating albumin of 58 gms. six months after injury. This rose to 79 gms. following therapy. In the chronic burn patient, body fat stores are largely exhausted, and the basal metabolic rate is reduced. Carbohydrate metabolism reflects the state of starvation present. The concentration of serum electrolytes may be within normal range but total body stores are depleted.

A severe, unremitting anemia is a feature of most patients, which reflects a combination of malnutrition and chronic hemorrhage from wounds elicited by dressing changes. Equally important may be the adverse effect of chronic sepsis on hematopoesis as cited by Wintrobe and Cartwright (6).

Metabolic restoration of the patient with chronic burn wounds is accomplished by measures which support the concept that these patients are debilitated through starvation. The factors leading to the debility are excessive undiminishing losses of protein, hemoglobin, fluids and electrolytes from wounds, and inadequate attention to nutritional requirements. Chronic sepsis augments these losses and increases the metabolic demands on the host. It was long ago demonstrated by Madden and Whipple (18) that in the presence of a deficiency of both hemoglobin and tissue protein, priority is assigned to the fabrication of new hemoglobin. Therefore it logically follows that restoration of protein deficits may be expedited by initial correction of anemia. This means that whole blood transfusions theroretically assure the deviation of newly available protein to synthesis of tissue and plasma proteins (7). Frequent transfusions in association with increased dietary intake rapidly restore the hematocrit, circulating protein, and red cell mass to near normal levels (Figure 3).

There is much which is controversial concerning the merits of positive nitrogen balance with reference to postoperative and post-traumatic states (1, 13, 20). There is evidence to suggest that wound healing may proceed to completion in the protein-starved subjéct, although at a retarded rate (11). There seems little doubt, however, that prolonged negative caloric and nitrogen balance are incompatible with the welfare of the patient as a whole, even though the healing processes may not immediately reflect this fact. Furthermore, there is increasingly more efficient utilization of ingested nitrogen by such patients after the acute recovery phase and on this basis the severity of their needs is extreme (12).

We noted improvement in mental attitude and appetite after institution of a modified androgen (Nilevar®)* in three patients. Although the duration of the anabolic effect is known to be transient, it may be sufficient to initiate the metabolic recovery with increased appetite and a sense of well being. Artz and Reiss (2) are strongly opposed to the use of ACTH and cortisone and with this we concur.

PLAN OF WOUND MANAGEMENT

In the selection of the proper time to attempt definitive surgical repair we rely relatively little upon the appearance of the wounds, but tend more to plan on the basis of the patient's general condition. Persistent weight gain, coupled with improved dietary intake, are probably the most reliable criteria for successful grafting. As a group, these patients represent the most adversely motivated and negativistic human beings one will ever see, and yet the worst will usually respond to a firm but considerate program of self assistance. Although it was occasionally necessary to resort to tube feedings, oral feedings were eventually well received by the majority of our patients. We are convinced that initial emphasis upon whole blood transfusions contributes much towards overcoming the anorexia problem. The favorable effects of personal contacts and constant encouragement, however, can not be overemphasized.

During the period of nutritional restoration preceding surgery a concentrated effort is made to diminish the surface infection of wounds. We prefer hydrotherapy in the form of detergent baths in the Hubbard tank at least once daily if the patient will tolerate this routine. Blood loss with dressing changes may be excessive with chronic burns despite the relatively avascular state of granulation tissue. Deeper wounds about skeletal prominences and joints often contain larger vessels with fragile coverings which dislodge with dressings. Performing dressing changes with the use of the tub or the tank minimizes hemorrhage from these sites and illustrates one of the greatest advantages of this routine, in addition to reducing the demand for narcotics and anesthesia. The occasional patient will not tolerate management in the tank because of extreme apprehension or a fear of water in which case we have instituted once or twice daily dressing changes, preferably with only analgesia provided by Meperidine®. Narcotic addiction is an ever present threat to these patients, most of whom resist all phases of treatment initially unless accompanied by pain medication or anesthesia. A relatively inflexible program of gradual withdrawal coupled with the transient use of tranquilizing drugs or sedatives has been our only effective system of defense. When drug addiction has been previously established we have had little success in improving dietary intake until this problem has been controlled.

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* Furnished through courtesy of G. D. Searle & Company, Chicago.

Patients with long-standing unhealed burned wounds of the trunk and extremities have usually existed without benefit of scheduled position changes to alleviate the pressure on wounds. The wound problem in the late stages then becomes a double entity. The original sites of skin destruction due to thermal injury coupled with infection then persist in the completely bedridden patient in a manner comparable to a massive pressure ulcer. In this type of patient although granulations may appear to be receptive for grafts, definitive wound coverage will not be accomplished if the patient remains immobile. For this reason we begin at the outset to institute a program of scheduled position changes and to increase the patient's capacity for physical activity. This usually necessitates a period on a Stryker or Foster frame. A device which we have found quite useful, particularly in the management of patients with burns over the upper trunk and limbs, who have legs relatively free from injury, is the Circolectric bed (Figure 8). This is an electrically motorized bed which may be activated by push button to turn in a vertical axis. It may serve the function of a tilt-board or facilitate alterations in the patient's position during postoperative

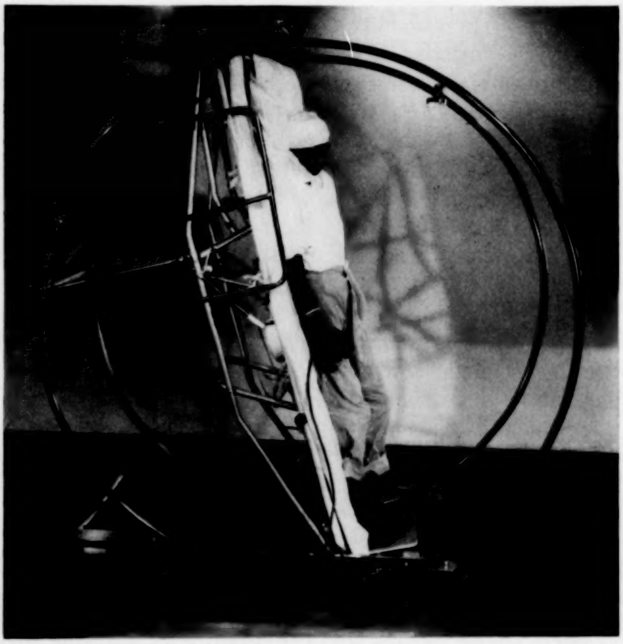

FIG. 8. Photograph of patient on electrically operated turning frame.

recovery from anesthesia and for the management of hypotension. Perhaps its most important feature is that it reduces the number of personnel required to ambulate the patient with severe burns and affords him a greater sense of independence.

The wound flora most resistant to treatment among these patients have been pseudomonas and staphylococci. In our hands, the single most effective method for dealing with the problem of local infection of all types has been detergent baths. Topical Bacitracin has been of aid in the management of most wounds inhabited by the staphylococci (4) and Polymyxin B ointment has assisted in the gross cleansing of most wounds infected with pseudomonas (14). Drugs are selected for topical use on the basis of laboratory determination of sensitivity patterns. The above named drugs plus Neomycin® have been most effective. We have used systemic antibiotics very rarely except for penicillin immediately before and after grafting patients whose wounds harbor the Group A hemolytic streptococcus. The definite, although transient, effectiveness of systemic antibiotics has been reported in the management of the acutely burned patient (17). It is doubtful, however, that the scarred fibrotic beds of chronic wounds are likely to permit permeation of antibiotics in sufficient concentration to be effective.

When wounds of long standing have become fibrotic, indolent, devoid of active granulations and "permanently" infected, it is generally recommended that they be excised down to healthy tissue and grafted (2). Although we agree with this procedure in principle there is considerable difficulty in accomplishing this goal in the severely debilitated burned patient. Often there is little more than a transparent covering overlying the ribs, spine and other bony parts. Therefore complete excision of the fibrotic base of the wounds in many of these patients is not feasible. In dealing with the more refractory wounds we have performed the debridement as a single separate stage and grafted after two but not longer than five days later as recommended by Blocker (5). The interval between debridement and grafting is used to condition the more unsatisfactory wounds with topical antibiotics, proteolytic enzyme preparations, or continuous wet dressings (10). When grafting wounds which have continued to show an exudative phase in spite of intensive local care, we have maintained wet dressings post-operatively by continuous saturation with 1% neomycin solution. We have also had success with the use of saline only as a wetting agent. After six to eight days following grafting procedures, detergent baths are resumed as soon as is practical. Unless this is done the wounds of many patients will develop minute foci of infection in areas of graft failure which will spread and consume grafts in adjacent zones in spite of daily dressing changes.

In our hands the grafting of large chronic wounds over the trunk has been relatively unsuccessful unless the patient was able to adapt to a certain position with the grafted side up for several days post-operatively. We have given up trying to graft simultaneously the anterior and posterior aspect of the body and prefer to concentrate first on the back. Once the back regains tolerance for the pressure of recumbency, the problem in closing anterior wounds diminishes.

ANESTHESIA FOR BURNED PATIENTS

Because of the severe physiologic and metabolic disturbances, administration of anesthesia to burned patients is always a challenge. The administration of multiple anesthetics in short intervals adds further stress to the already depleted reserves of the body.

Psychologically, the burned patient is very apprehensive and extremely fearful of repeated anesthetics, but often demands anesthesia for the simplest of procedures. Preoperative visits by the anesthesiologist are very reassuring and helpful. A little extra time spent by the anesthesiologist during the pre-anesthetic visit will be amply repaid by the patient's increased confidence. Careful review of the patient's history and laboratory data will familiarize the anesthesiologist with the patient's general condition and help to plan a safe and successful anesthetic.

Dressing changes and cleansing can usually be performed under intravenous Meperidine®. In the average patient, 100 mg. of Meperidine®, diluted five times volume in the patient's blood or saline, given slowly five to ten minutes before the procedure is very satisfactory. Minor skin grafts can be carried out by local infiltration with ½% Xylocaine®. When general anesthesia is necessary Meperidine® and atropine are given intramuscularly an hour before the operation. Meperidine® is preferred to morphine because a comparable dose of Meperidine® achieves the same degree of sedation with less depression (21, 22). The choice of anesthetic agents or methods depends on the length of the procedure and the degree of the operative stimulation. When inhalation anesthesia is planned, special attention must be focused constantly upon the respiratory and circulatory systems, since no type or degree of anoxia should be permitted. Because of the presence of low hemoglobin levels, patients may suffer from hypoxia without apparent cyanosis. Combinations of sodium pentothal, nitrous oxide and oxygen can be used for short and less stimulating procedures.

Cyclopropane is the preferred anesthetic agent for major operative procedures on burned patients. Pleasantness of induction and potency, which allows a high oxygen content in the anesthetic mixture, help to obtain an adequate and reversible surgical anesthesia without an overdosage or disturbance of the patient's physiologic processes.

It should be emphasized that delicate decisions frequently have to be made concerning supportive therapy. Blood volume should be maintained. An adequate route for intravenous fluids should be started prior to induction. In instances when the patient has to be shifted from one position to another during the procedure we have found the Rochester plastic needle very useful (19).

FURTHER PROBLEMS OF CONVALESCENCE

When major wound defects are finally closed in these patients much still remains to be accomplished before definitive reconstruction of healed deformities may be planned. From the time of admission, the physiotherapy adjuncts of exercise, intermittent splinting, hydrotherapy, and ambulation aids are utilized with all patients. These measures resist progressive loss of function of joints already being affected by contracture of healed wounds. A number of them have exhibited the familiar problem of recurrent epithelial breakdown, ulceration, and progressive scarring over areas initially covered by grafts. This is commonly observed over finger joints, shoulders, and back, particularly in areas subject to motion and stress. Exclusive of the effects of recurrent trauma, this appears to be a consistent property of very thin grafts. It is a well-established principle that the thinner the graft, the more likely the take, the thicker the graft, the less the scarring. We would not care to minimize the importance of early and complete grafting of extensive burn wounds, a goal which often necessitates rigid economy of donor sites; however, we suggest that certain areas which depend upon the integrity of a semi-elastic covering for maintenance of function, be selectively covered with split grafts of intermediate depth (2). We noted that thin grafts are especially prone to exhibit recurrent breakdowns over hands, shoulder joints, and lower legs.

The details of plastic reconstruction of deformities resulting from thermal injury constitute a special set of problems too complex for discussion here. The specific methods which we utilize are those commonly employed by others. The problems of each patient must be individualized. We defer all definitive reconstructive procedures such as pedicle flaps, capsulectomy, and arthrodesis until complete wound coverage has been attained with free grafts. We plan to send such patients home for a period of 3 to 6 months after wound closure is finally attained, before embarking upon a program of reconstruction. Many of them have already been hospitalized for 18 to 24 months, and a period of non-institutional existence becomes therapeutic, if not imperative.

SUMMARY

The chronic burn state is characterized by a vicious cycle of incomplete skin coverage, starvation, anemia, infection and failure of subsequent skin grafts. It is, unfortunately, a condition more easily prevented than treated. The successful management of these difficult patients must be conducted in the following stages:

1. Restoration of nutrition takes precedence and may be most expeditiously accomplished by placing initial emphasis on whole blood transfusions. A simultaneous program of nitrogen and caloric repletion is needed to reverse the changes of chronic starvation.

2. Aggressive, sustained attention to open wounds must be maintained until the optimum time for grafting occurs. Meticulous wound care during the period of nutritional repletion, followed by excision of fibrotic tissue and grafting, assures more successful wound coverage.

3. After complete wound coverage has been accomplished, definitive reconstruction of healed deformities and long term rehabilitation may then be planned electively.

REFERENCES

1. Abbott, W. E., Davis, J. H., Benson, J. W., Krieger, H. and Levey, S. Metabolic alterations in surgical patients. VI. The effect on weight and nitrogen balance of

providing varying caloric intakes by intravenous carbohydrate, fat and amino acids in gastrectomized patients. Surgical Forum, **5:** 501–509, 1954.

2. Artz, C. P. and Reiss, E. *The Treatment of Burns*, W. B. Saunders Co., Philadelphia, 1957.
3. Benson, J. W. and Holden, W. D. Serum properdin titers in surgical patients. Surgical Forum, **8:** 121–124, 1959.
4. Blocker, T. G., Jr., Bass, J. A., Lewis, S. R. and Eade, G. G. General aspects of microbial growth in the burn wound. Am. J. Surg., **95:** 309–311, 1958.
5. Blocker, T. G., Jr., Snyder, C. C. and Lewis, S. R. Late treatment of severe extensive burns. South. M. J., **47:** 371–374, 1954.
6. Cartwright, G. E. and Wintrobe, M. M. The anemia of infection. XVII. A review. Advances in Int. Med., **5:** 165–226, 1952.
7. Clark, J. H., Nelson, W., Lyons, C., Mayerson, H. S. and DeCamp, P. Chronic shock: the problem of reduced blood volume in the chronically ill patient. Ann. Surg. **125:** 618–646, 1947.
8. Co Tui, Wright, A. M., Mulholland, J. H., Breed, E. S., Barcham, I. and Gould, D. Studies in surgical convalescence. II. A preliminary study of the nitrogen loss in exudates in surgical conditions. Am. Surgeon, **121:** 223–230, 1945.
9. Cope, O., Nardi, G. L., Quijano, M., Rovit, R. L., Stanbury, J. B. and Wight, A. Metabolic rate and thyroid function following acute thermal trauma in man. Ann. Surg., **137:** 165–174, 1953.
10. Eade, G. G., Bass, J. A., Lewis, S. R. and Blocker, T. G., Jr. Bacterial studies of the burn wound in relation to therapy and skin grafting procedures. Surgical Forum, **9:** 805–807, 1958.
11. Edwards, L. C. and Dunphy, J. E. Wound healing. New England J. Med., **259:** 275–285, 1958.
12. Hirshfeld, J. W., Williams, H. H., Abbott, W. E., Heller, C. G. and Pilling, M. A. Significance of the nitrogen loss in the exudate from surface burns. Surgery, **15:** 766–773, 1944.
13. Hubay, C. A., Kiehn, C. L. and Drucker, W. R. Surgical management of decubitus ulcers in the post-traumatic patient, Am. J. Surg., **93:** 705–713, 1957.
14. Jackson, D. M., Lowbury, E. J. L. and Topley, E. Pseudomonas pyocyanea in burns: its role as a pathogen, and the value of local polymyxin therapy. Lancet, **2:** 137–147, 1951.
15. James, G. W., III, Abbott, L. D., Brooks, J. W. and Evans, E. I. The anemia of thermal injury. III. Erythropoiesis and hemoglobin metabolism studied with N^{15}-glycine in dog and man. J. Clin. Invest., **33:** 150–162, 1954.
16. Kiehn, C. L. and Des Prez, J. D. The burnt hand. Am. J. Surg., **97:** 421–428, 1959.
17. Langohr, J. L., Owen, C. R. and Cope, O. Bacteriologic studies of burn wounds, Ann. Surg., **125:** 452–504, 1947.
18. Madden, S. C. and Whipple, G. H. Plasma proteins: their source, production and utilization. Physiol. Rev. **20:** 194–217, April, 1940.
19. Massa, D., Lundy, J. S., Faulconer, A. and Ridley, R. W. A plastic needle. Mayo Clin., Proc. Staff Meet., **25:** 413–416, 1950.
20. Moore, F. D. and Ball, M. D. *The Metabolic Response to Surgery*. Charles C Thomas, Springfield, Illinois, 1952.
21. Robbins, B. H. and Baxter, J. H., Jr. Studies of cyclopropane; the effect of premedication with morphine or amytal upon the heart rate, rhythm, and blood pressure in dogs under cyclopropane anesthesia. J. Pharmacol. & Exper. Therap., **68:** 85–95, 1940.
22. Taylor, H. E., Doerr, J. C., Gharib, A. and Faulconer, A. Effect of premedication on ether content of arterial blood required for surgical anesthesia. Anesthesiology, **18:** No. 6, 1957.
23. Whalen, W. P. Skin grafting in burns. S. Clin. North America, **39:** 421–434, April, 1959.

X-RAY TREATMENT OF CRUSH INJURIES

A Clinical and Laboratory Experiment

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*"Good clinical investigation is the touchstone of good surgical research now, just as it was with Lister and Halsted. The surgical investigator must be a bridgetender, channeling knowledge from biologic science to the patient's bedside and back again. He traces his origin from both ends of the bridge. He is thus a bastard, and is called this by everybody. Those at one end of the bridge say he is not a very good scientist, and those at the other say he does not spend enough time in the operating room." F. D. Moore**

A crush injury to any part of the body produces an injury in depth. When there is a hard surface behind the crushed part then the compressing force is greatly magnified and bursting of tissues results. In a hand or foot the damage involves all tissues between skin and bone frequently splitting the former and fracturing the latter.

The clinical problem results from the tremendous outpouring of tissue fluids, their subsequent "clotting" and final organization into fibrous tissue. In severe cases this fibrosis results in a virtually frozen hand or foot which has essentially no functional value.

The standard treatment for these injuries is elevation, pressure dressings, and early controlled activity. Recently, the addition of hyaluronidase or other spreading factors has been added to this treatment. Unfortunately this regime rarely produces good results and is not always compatible with the treatment of such concomitant lesions as skin loss and fractures.

Theoretically, it does not seem that this standard treatment is related to the natural pathological history of the condition. The essential lesion is the presence of protein-rich intra- and extra-cellular edema fluid. This fluid penetrates between all the moving parts and even between the individual cells. Fibrin is laid down and the whole becomes organized with the ingrowth of blood vessels and connective tissue until the hand or foot becomes "frozen".

In 1954 it was decided that the use of mild radiotherapy was justified in attempting to increase the rate of resolution of the swelling and to decrease the degree of fibrosis. It was felt that radiotherapy would be of use in three phases of the pathological process.

(1) by increasing the permeability of the cell membrane it would allow the intracellular oedema to drain out;

(2) by inhibiting the formation of young fibroblasts it would decrease the fibrous organization of the damage area;

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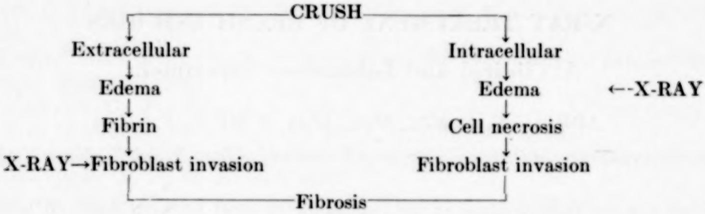
* The University in American Surgery, Surgery, **44:** 1 (July), 1958.

(3) probably by enzyme inactivation the yield of fibrin would be reduced.



It is generally felt that x-rays produce their main effect upon dividing cells and on cell nuclei. But it has been shown that they also affect intracellular fluid and enzymes as well as the cell membrane. It has been known for many years that small doses of x-rays can affect the permeability of cell membranes. This effect is demonstrated by injecting a dye (such as lamp-black) which normally does not permeate into the cell, and then irradiating the tissues. Sections will show that the carbon particles have passed into the intracellular fluid. It would seem a reasonable assumption that this cell membrane will allow two way traffic and permit outward drainage of intracellular edema fluid.

It is known that all dividing round cells are extremely radio-sensitive and that the proliferation of fibroblasts is also inhibited by irradiation. Small doses of x-rays accelerate the resolution of inflammatory swellings and have been used for many years in the treatment of carbuncles. Similar doses have been shown to have an inhibitory effect on the change from fibrinogen to fibrin. The dose used was small, 50 r being given on alternate days to an average total dose of 150 r. In some early cases a total of 300 r was used but experience soon showed that a dose of this order was not required.

By 1956, 46 cases had been treated and the results were reported before the Royal Society of Medicine. All the injuries treated were of only moderate severity and involved either a hand or foot. Many of the cases treated still had sutures in skin wounds, some had split skin grafts in situ and others had fractures of the phalanges, metacarpals or metatarsals. Several cases had combinations of these injuries. There appears to be no theoretical objection to the treatment of cases which have metal pins transfixing fractures or in which an abdominal flap has been used to replace skin loss. A follow-up of the first 15 cases is recorded in Chart #1.

Since this initial series further cases have been treated bringing the total to over 50.

At the time of the original review it was stated that while an unbiased scientific assessment of the result of treatment of these cases was impossible it could be stated that a very definite clinical impression was formed that the cases got relief from symptoms and returned to work more quickly than similar cases treated by accepted methods.

After this preliminary report had been given, two cases of bilateral crushed feet were treated under controlled conditions. In both cases it was planned to give x-ray treatment to only one foot but to pretend to treat both feet so that the patient was unaware of any difference. The doctor in charge of the case and the consultant radiotherapist were aware of these conditions but did not know which foot had been treated.

In both cases the patients volunteered the impression that one foot felt considerably less painful than the other within 24 hours of the first treatment. Clinically the differentiation was not obvious for 48 hours but after this time there was obvious difference in the extent and tenseness of the swelling of the feet. The circulatory return after pressure blanching was considerably more rapid in the treated than the untreated foot.

The subsequent clinical progress continued to show marked difference with the patient being able to bear weight and wear his normal shoe on the treated foot at least a week earlier than the untreated foot.

After reviewing these clinical results it was decided to carry out a similar investigation under controlled laboratory conditions.

Rats tails were chosen as the experimental material. Despite the fact there is little subcutaneous tissue in these tails it was felt that there was probably sufficient for the purposes of this pilot study. (The only animal with skin and subcutaneous structures comparable to humans is the pig—an awkward animal for such investigations!)

A crushing apparatus was constructed and tests established a method for producing a standard crushed area (Figure 1).

Expt. 1: A series of experiments using a template with varying diameter holes showed that there was a more rapid return to normal diameter in crushed tails which had been x-rayed when compared with a non-x-rayed control. There did not appear to be any consistency in the results when varying doses of x-rays were given. There was, however, a definite indication that the crushed area recovered more rapidly when the x-ray treatment was given early after the crushing (Figure 2).

Isotope tracing was chosen as the method to demonstrate whether the subsidence in the swelling was due to an increased rate of clearance following the x-ray treatment. Because of the long half-lives of carbon isotopes, it was decided to use colloidal radio-gold as the indicator.

Expt. 2: Subcutaneous injections were made into crushed and uncrushed rat tails. Sections were taken of these areas and examination showed that in the uncrushed tissues the clumps of gold which had not been ingested by phagocytes were extra-cellular in relation to structural tissue cells. In those tissues which had been crushed there was definite evidence of intracellular clumping of colloid.

It seemed therefore that there was a basis for proceeding with radio-gold as the signal.

Expt. 3: A preliminary metabolic study was set up to trace the distribution of the gold in the body tissues. Two rats were injected with an equal dose of radio-gold, one having its tail crushed immediately after injection. Daily readings were taken of the total body, the tail alone, the 24 hours output of urine and the 24 hours output of feces. The study continued for a week. Only for the first

	Age	Occupation	Injured at Work	Site Injured	Mode of Injury	Associated Fractures	Surgical Treatment	K.V.	m.A.
1	58	Labourer	Yes	Great toe and dorsum of foot	Full oil drum dropped.	Phalanges	Dressings.	140	5
2	31	Scaffolder	Yes	Great toe and dorsum of foot	Steel scaffolding weighing 56 lb. dropped.	Distal phalanx	Tulle gras and dressings.	140	5
3	64	Salesman	No	Index finger	Hit with hammer.	Distal phalanx	Tulle gras and dressings.	140	5
4	27	Asphalter	Yes	Great toe	8 lb. block of asphalt onto toe.	Distal phalanx	Trephine of nail for haematoma. Dressings.	140	5
5	42	Dustman	Yes	Whole hand excluding thumb	Trapped under heavy hopper.	Nil	Lacerations sutured. Dressings.	140	5
6	33	Drayman	Yes	Middle and ring fingers	Crushed between full beer barrels.	Terminal phalanges	Evacuation Haematoma. Dressings.	140	5
7	27	Packer	Yes	Whole foot	2½ cwt. girder fell 4 feet.	2, 3, 4, 5 metatarsal shafts.	Dressings. Below knee plaster. Non-weight-bearing.	220	15
8	26	Builder	Yes	Index and middle fingers	"Heavy" girder fell on hand.	Nil	Dressings to finger abrasions.	140	5
9	48	Policeman	No	Great toe	14 lb. engine fell on toe.	Terminal phalanx	Dressings.	140	5
10	32	Labourer	Yes	Whole forefoot	24 lb. casting fell 3 feet onto foot.	All terminal phalanges and shaft of metatarsal 3.	Below knee walking plaster.	140	5
11	53	Engineer	Yes	Great toe	Unknown weight on to toe.	Terminal phalanx	Dressings.	140	5
12	64	Bank porter	Yes	Whole forefoot	3 cwt. cased machinery on to foot.	Nil	Dressings.	140	5
13	34	Stonemason	Yes	Whole hand	¾ cwt. stone block on to dorsum of hand.	Nil	Nil.	140	5
14	53	Coiner	Yes	Middle finger	Heavy spanner crushed finger against bench.	Terminal phalanx	Suture of wound. Dressing.	140	5
15	33	Labourer	Yes	Little finger	Caught in runner of hoist.	Nil	Split skin graft to dorsum.	140	5

day did the feces show a measurable quantity of radiation. Even then the proportion of the feces count to the total body count was of the order of 0.5%. After the first reading both urine and feces counts were of such a small order that the amount was negligible in comparison to the total body or the tail counts.

The total body counts correlated closely with natural decay of gold (Figure 3). But the tail readings showed a considerably greater clearance from the uncrushed tail in comparison with the crushed tail. It was possible to conclude that the crushed tissue retained, or prevented the clearance of, the isotope.

RT 1

Radiotherapy					Days off Work	Clinical Results	Comment
Filter	F.S.D.	Total γ	Fractionations	Total days			
1 mm. Al	15	150	3	5	27	Poor: slow resolution of oedema and pain.	"Treatment did me no good" but patient was astonished to hear he had walked all the time on a fractured toe.
1 mm. Al	15	150	3	6	14	Good. Pain and throbbing went after first treatment.	"Friends with similar injuries took 4-7 weeks off work. I was back in 2 weeks."
1 mm. Al	15	150	3	5	Nil	Good. Rapid resolution of throbbing and has soft non-tender finger pulp.	Was kept awake by throbbing the night after the accident but after first treatment slept well since symptoms gone.
1 mm. Al	15	150	3	5	6	100% Functional recovery in one week.	Compared with a previous similar accident patient surprised by rapidity of "cure."
1 mm. Al	15	150	6	14	28	Good. Full function within 2 weeks of start of treatment.	Treatment not started until a week after injury. Lacerations healed by first intention.
1 mm. Al	15	150	3	5	10	Good. Full function within 9 days of injury.	"Off 10 days but judging by other fellows I should have been off a month."
1 mm. Al + 0.5 mm. Cu	50	300	6	11	71	Full union of fractures which were compound from within. Fully functioning painless foot.	Swelling of dorsum went rapidly and necessitated early change of plaster. All pain went within 4 days.
1 mm. Al	15	150	3	6	7	Normal hand; no residual thickening.	All throbbing gone in 48 hours.
1 mm. Al	15	150	3	5	12	Good. Soft and non-tender pulp of the toe.	"I passed the remark to the wife how much the 1st treatment had eased the pain and throbbing."
1 mm. Al	15	150	3	6	25	Good. A normal foot.	Within a month could stamp heavily on foot and was working.
1 mm. Al	15	300	6	12	2	Good. Two months before all thickening of terminal phalanx subsided.	"My mates lay off a month for things like this—couldn't understand why I was back so quick."
1 mm. Al	15	300	6	15	49	Good. Fully weight bearing with no tenderness or residual swelling.	Arrived 2 weeks after injury with a shiny swollen foot with pitting oedema up to 4" above malleolus. Within 4 days of start of treatment almost all throbbing and pain gone.
1 mm. Al	15	300	6	12	7	Good. Within 2 weeks had full function.	"The boys said I was fit for a month's holiday but I was back in a week."
1 mm. Al	15	150	3	6	Nil	Good. A normal finger tip with normal sensation.	A virtually complete amputation with the whole finger tip supported by one digital artery; it survived and he has a good finger.
1 mm. Al	15	100	2	3	4	Perfect take of graft but lack of full extension of D.I.P.	Worked with graft sewn in place. Its healing was not affected by radiotherapy.

Expt. 4: In the next experiment daily readings were taken from 24 rats divided into groups of 6.

Group 1: Gold injection, crushed and 100 r treatment.

Group 2: Gold injection, not crushed and 100 r treatment.

Group 3: Gold injection, crushed and no x-ray treatment.

Group 4: Gold injection, not crushed and no x-ray treatment.

By cross reference between these 4 groups it was planned to—

1) Assess the effect of x-ray on isotope clearance rate of crushed tails.

2) Determine whether x-ray had any effect on the isotope clearance from uncrushed tails.

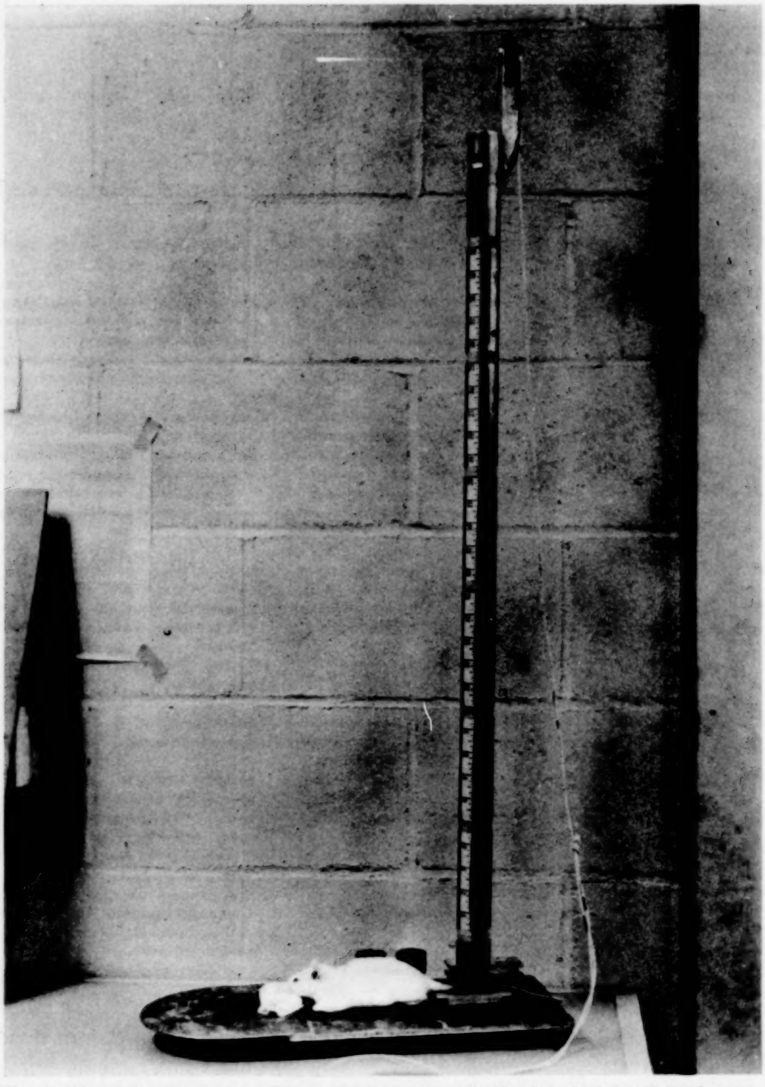
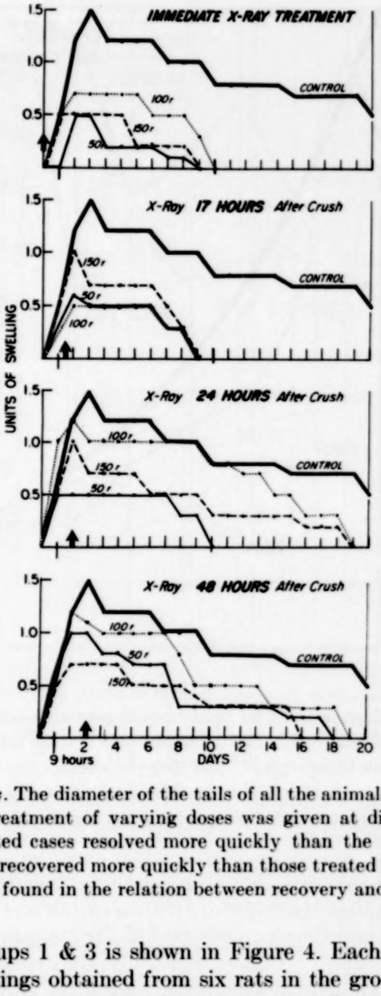


FIG. 1. *Crushing Apparatus.* The animal was anesthetized and the tail held securely between 2 templates so cut that each groove represented ⅓ of the circumference of the tail. The upper cylindrical block containing a groove was struck from above by a cylindrical lead block falling from a measured height within the vertical cylinder. The weight can be seen at the 23rd vertical mark.


IMMEDIATE X-RAY TREATMENT

X-Ray 17 HOURS After Crush

X-Ray 24 HOURS After Crush

X-Ray 48 HOURS After Crush

FIG. 2. *Template Tests*. The diameter of the tails of all the animals were measured before being crushed. X-ray treatment of varying doses was given at different time intervals. The swelling in all treated cases resolved more quickly than the control. Those treated within the first 24 hours recovered more quickly than those treated in the second 24 hours. No consistency could be found in the relation between recovery and dose given.

Comparison of groups 1 & 3 is shown in Figure 4. Each point on the graph is the average of readings obtained from six rats in the group. When the mean error of these readings is plotted against the natural decay of gold there is no great difference in these figures.

Perhaps it can be said that there is a possible significance in the persistently higher clearance rate of the x-rayed than the non-x-rayed.

When groups 2 & 4 were compared there was even less significance between the figures and it was shown that there was no demonstrable effect of x-ray upon the rate of radio-gold clearance from uncrushed tissues (Figure 5).

From the gold series therefore we find we can probably assume that the crushed tissues retain the isotope and that the x-ray treated tails have a higher rate of clearance than the non-x-rayed. However, the spread between the line of

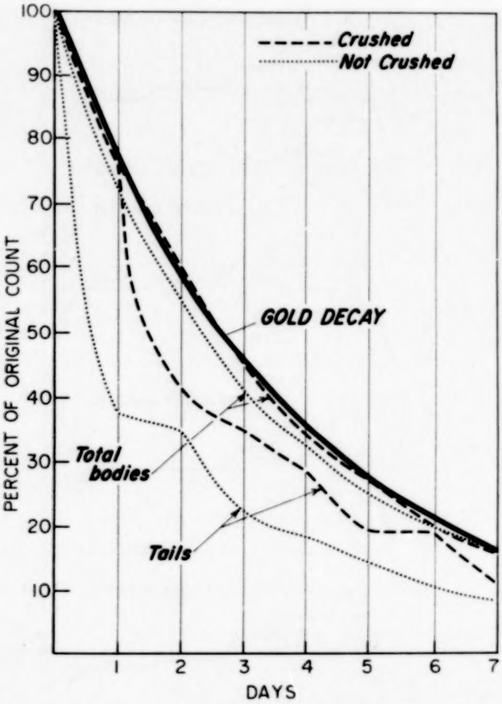


FIG. 3*a*. *Metabolic Experiment.* The total body counts correlate closely with the figure for the natural decay of radio-gold. The difference between the tail readings does appear to show a greater retention of isotope in the crushed tissues.

gold decay and the experimental figures was so small that other isotope signals were tried.

Expt. 5: The next material chosen was Iodine prepared either as NaI or as RISA. It was found that there was a very considerable difference between the decay rate of Iodine and the clearance rate of the compounds. In fact the clearance rate was so fast that it appeared doubtful if they could be used successfully. When 4 groups of 6 animals were compared using the two iodine compounds no significant difference could be shown between the clearance rates of the x-rayed and non-x-rayed tails (Figure 6). In view of the earlier figures obtained with the gold series it seems probable that the lack of difference between the x-rayed and not x-rayed could be explained by the rapid clearance rate possible for the relatively small particle size of the Iodine molecule.

Expt. 6: Before further experiments were carried out RISA was studied to see whether a build-up could be shown in the crushed tissues. Previously sections taken from the tails of the rats used in the gold metabolic studies (Expt. 3) had shown that there was a retention of the isotope in the crushed tissues but that no detectable amount was carried into the tail distal to the site of injection.

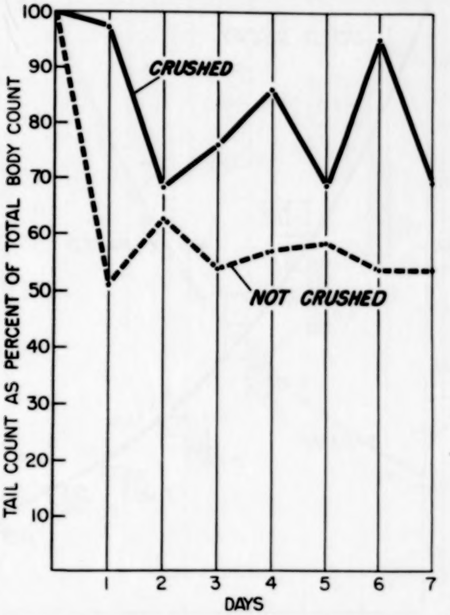


FIG. 3*b*. *Metabolic Experiment.* When the figures of tail clearance are expressed as a percentage of the total body count the clearance rate of the uncrushed tail is persistently greater than that of the crushed tail. The rate of clearance of the uncrushed tissues is relatively constant but there is a time lag before clearance commences from the crushed tissue.

A single rat's tail was injected with RISA distal to the crushed area 48 hours after crushing. The animal was sacrificed 3 days after the injection and four sections of the tail were taken for counting and for autoradiographs (Figure 7). The figures showed the greatest concentration of isotope to be at the injection site and the least concentration at the base of the tail proximal to the crushed area. Two sections were taken within the crushed zone and the area nearer to the injection site showed a lower isotope count than the more proximal area. Thus it was shown that the swollen area trapped the RISA and proved to be a barrier to its passage into normal tissue. It was felt that these results provided sufficient background information to plan a larger series of tests.

The apparatus used for these RISA studies is shown in Figure 8. A standard set up was established; the counting head being directly over the injection site and shielded from any background interference. The animal was held in a cone-shaped holder and kept in place by a large lead shield. The head end was open and water was available from a drip-bottle. The tail was held immobile in a plastic tube clipped to a base board. The whole assembly was tipped towards the head to avoid urine contamination such as was recorded in the NaI experiments (Figure 6). The counts were monitored onto an Esterline-Angus continuous strip to eliminate any human counting errors. Two tenths cc. of RISA con-

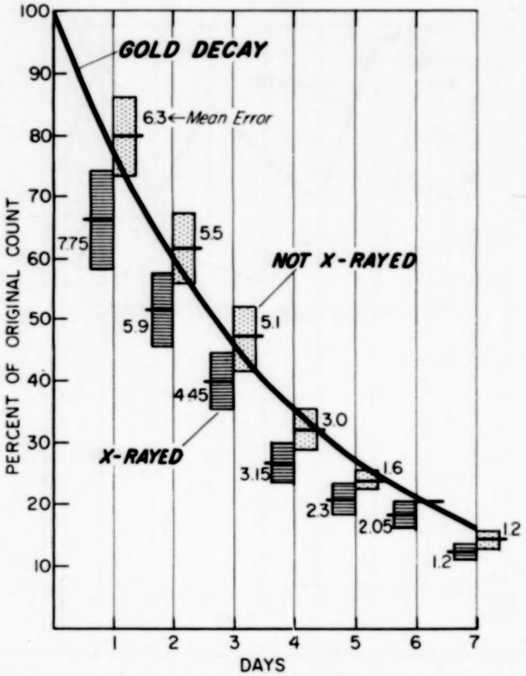


FIG. 4. *Experiment 4.* When the mean error for the average of 6 rats in the two groups x-rayed and not x-rayed is plotted no significant difference can be seen between these figures and the natural decay of radio-gold.

taining 20 μc was the standard injection dose. Thirteen animals were used in this RISA series. Animal #1 was run as a preliminary trial on a different recording apparatus.

Expt. 7: Animal #1 was placed in the standard holder but in this case a dual Rectiriter was employed using two scintillation probes. One was placed over the injection site and shielded as in Figure 8. The other was left exposed and used to monitor background radiation. The results of this test showed a gradual clearance of the RISA from the injection site in the normal tail and a very low but steady level of background. With this information it was possible to standardize conditions for the remaining 12 animals.

Expt. 8: The animals were treated as follows:

#2 Normal control		
#3 Crushed		Injection distal to crush site
#4 Crushed		Injection into crush site
#5 Crushed	Immediate x-ray 100 r	Injection distal to crush site

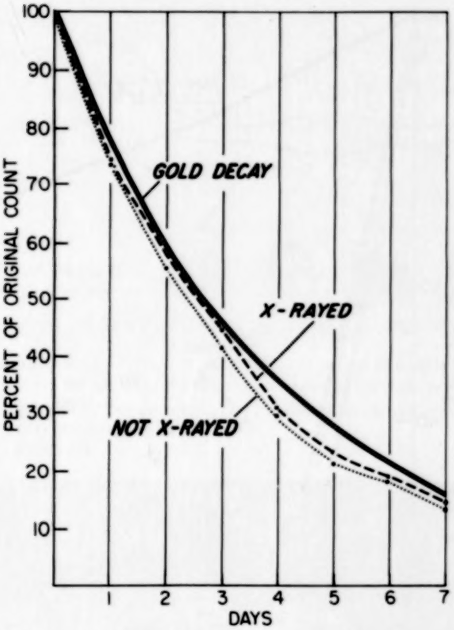


FIG. 5. *X-ray on Normal Tissues.* Comparison between irradiated and non-treated normal tails did not show any demonstrable effect of the x-ray on the clearance rate.

#6 Crushed	48 hours delay		Injection distal to crush site
#7 Normal control			
#8 Crushed	48 hours delay		Injection into crush site
#9 Not crushed	Immediate x-ray 100 r	24 hours delay	Injection into x-ray site
#10 Not crushed	Immediate x-ray 100 r	48 hours delay	Injection into x-ray site
#11 Crushed	24 hours delay x-ray 100 r	24 hours delay	Injection into crush site
#12 Crushed	Immediate x-ray 100 r	24 hours delay	Injection into crush site
#13 Crushed	Immediate x-ray 100 r	48 hours delay	Injection into crush site

As the figures for the RISA series began to collect it was found that the readings were persistently lower than the clearance of the control. Because of this a further control was run and found to be similar to the first. The control charted in the figures is an average of these two animals. A possible explanation for this increase in clearance is that RISA is a foreign protein to the rat since human albumen is an integral part of the compound. Such a foreign protein would provoke a prompt reaction by body mechanisms over and above any stimulus

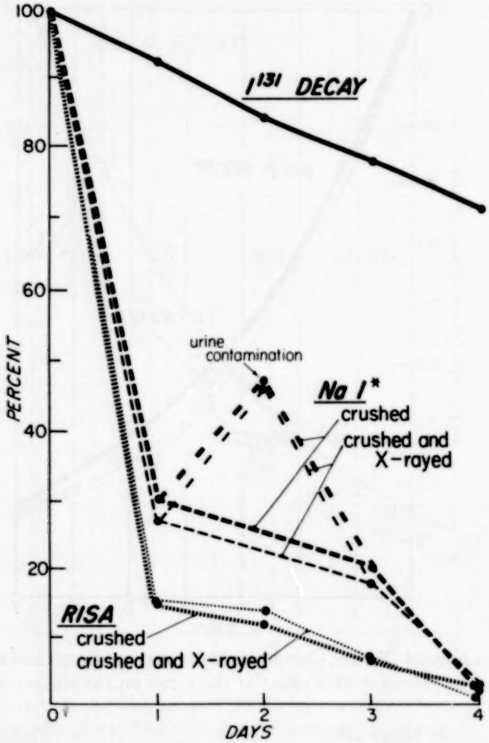


FIG. 6. *Iodine Trial.* Use of RISA and NaI showed a very rapid clearance rate and a great differential between the natural decay of I^{131}. No demonstrable difference could be shown between the x-rayed and non-treated animals.

that crushing or x-ray might provide. Such a reaction to foreign protein would take some hours to build up and a little support may be given this view by comparing the results of early injection and injections after a 48 hours delay. If animals #9 and #10 are excluded because their tails were not crushed it can be seen that the "less than 48 hours" group tend to collect near to the control while the "48 hours delay" group although smaller in number does show a greater spread (Figure 9).

The results for the four animals in which x-ray treatment was given to crushed tails show a clearance consistently greater than the control (Figure 10). Such figures would be reassuring if it were possible to ignore the persistently faster rates of clearance discussed above. On theoretical grounds one would expect that the greatest rate of clearance would be in an animal which had been given x-ray 24 hours after crushing since the radiation would then affect the inflammatory process at an early stage. In fact this animal, #11, showed a clearance rate virtually comparable to that of the control.

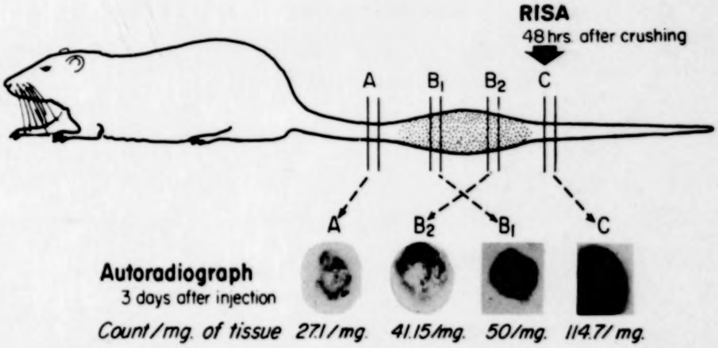

RISA
48 hrs. after crushing
A
B$_1$
B$_2$
C
A
B$_2$
B$_1$
C
Autoradiograph
3 days after injection
Count/mg. of tissue
27.1/mg.
41.15/mg.
50/mg.
114.7/mg.

FIG. 7. *RISA Clearance Study*. Sections were taken from an animal's tail which had been crushed 48 hours prior to injection. The sections were taken 3 days after the injection, counted and used to make autoradiographs. The swollen area traps a considerable proportion of the RISA.

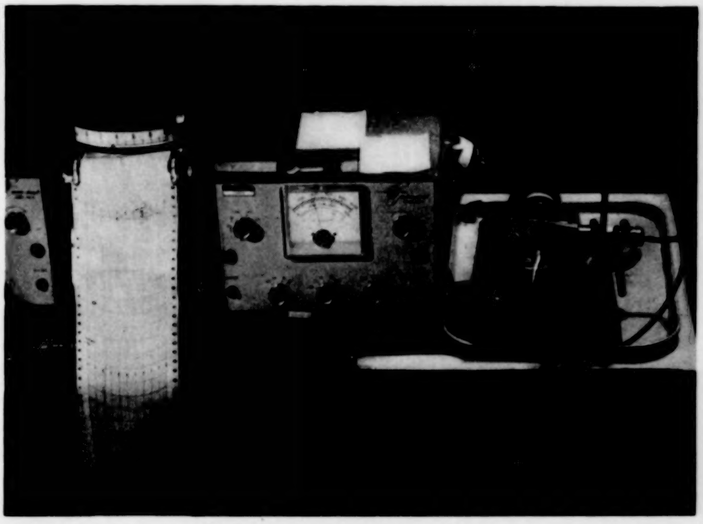
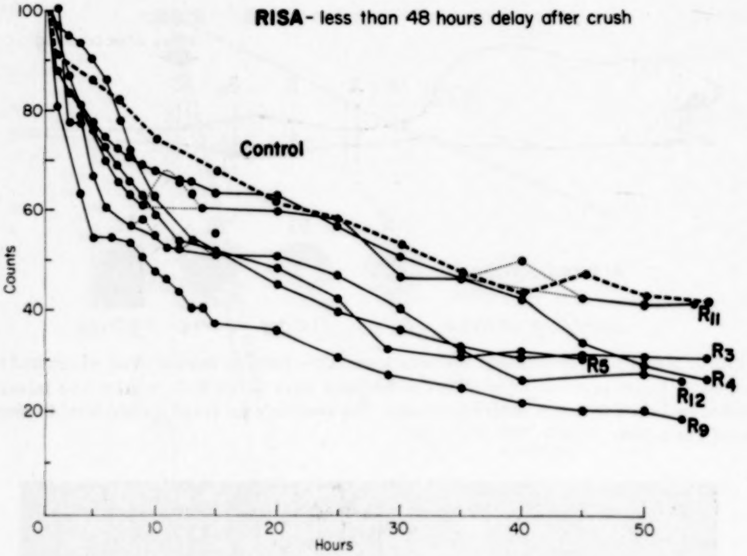


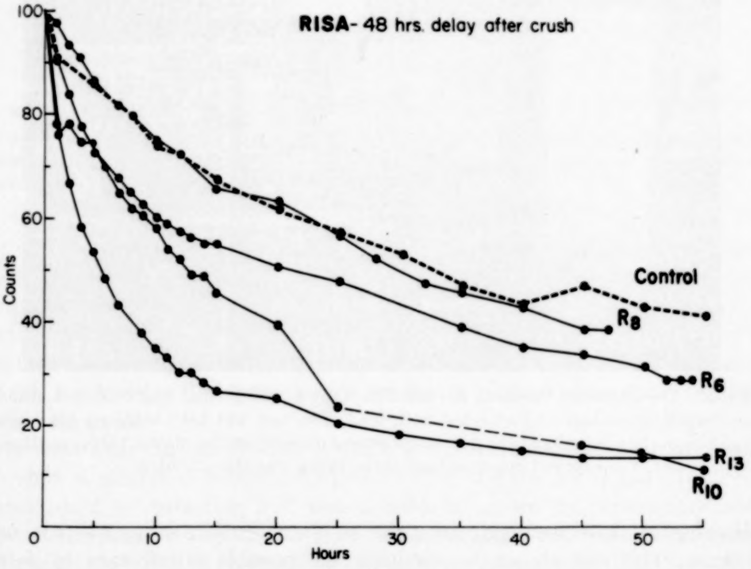
FIG. 8. *The Standard Counting Set-up*. The body of the animal was held in a standard cone-shaped rat holder and shielded with lead. The tail was held within a plastic tube clipped to the baseboard and the probe was placed directly on the plastic tube over the area to be counted. The exposed upper surface of the probe was also shielded.

Because of these seemingly irregular results a further series was run using Diodrast. This was chosen to eliminate the possible interference by foreign protein reaction and also to use a particle of larger size than NaI.

The physical plant apparatus used was identical with that used in the RISA series and the injection contained approximately 15 μc in 0.2 ccs.



a



b

FIG. 9. *Experiment 8*. The readings for this group are persistently lower than the control. Possibly the reaction of the rat's tissue to the human albumen in the RISA may have some influence on the figures. The "less than 48 hours group" (9A) tend to collect nearer to the control than do the "over 48 hours" group (9B).

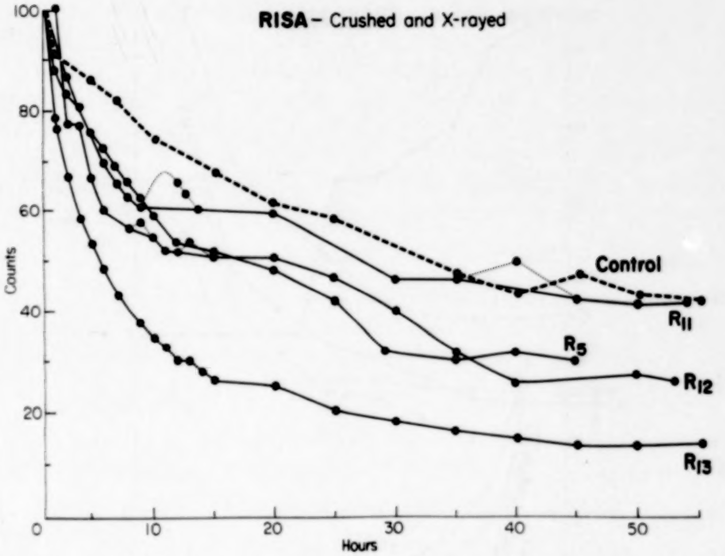


FIG. 10. *RISA and X-rayed Crush Injuries.* Examination of these results alone shows a clearance consistently greater than the control but these figures must be compared with those in Figure 9.

Expt. 9: Ten animals were used in this Diodrast series, one being a control in which the rate of clearance for the isotope from normal untreated tissues was established. The remaining animals numbered 1–9 were treated as follows:

#1 Crushed	48 hours delay		Injection distal to crush site
#2 Crushed	24 hours delay		Injection into crush site
#3 Crushed	Immediate x-ray 100 r	48 hours delay	Injection into crush site
#4 Crushed	Immediate x-ray 100 r	24 hours delay	Injection into crush site
#5 Not crushed	Immediate x-ray 100 r	24 hours delay	Injection into x-ray site
#6 Crushed	24 hours delay x-ray 100 r	24 hours delay	Injection into crush site
#7 Crushed	24 hours delay		Injection distal to crush site
#8 Not crushed	Immediate x-ray 100 r	48 hours delay	Injection into x-ray site
#9 Crushed		48 hours delay	Injection into crush site

Contrasting animals #1 and #9 it is seen that they are at opposite extremes of the graph but both animals were injected 48 hours after crushing (Figure 11). #1 was injected distal to the crushed tissues and shows the damming up effect of

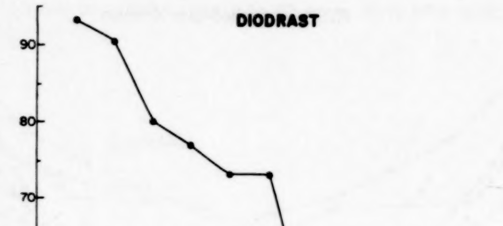


FIG. 11. *Experiment 9.* In these animals Diodrast was used under a series of different experimental conditions. It can be seen that there is a spread of results either side of the control. Detailed discussion will be found in the text.

the fully developed tissue fluid stasis. The extremely rapid clearance of #9 when the isotope was injected into the crushed area is hard to explain. It can be seen that total clearance has occurred within one hour. Perhaps in this instance the injection was immediately adjacent to a large and still patent blood vessel which rapidly carried away the isotope.

While it is possible to invoke a convenient blood vessel in the case of animal #9 no such explanation can be used for animal #7 whose clearance rate parallels that of the control but is significantly greater. One would have expected an injection given distal to an area crushed 24 hours previously to be slow in clearance and to have resembled the curve of animals #1, #2, or #3.

Animals #2 and #3 both showed a slower rate of clearance than the control. #2 was injected into the crushed site 24 hours after injury and showed a similar, but not so great, damming up of the isotope as #1. The curve of animal #3 lies between #1 and #2. This animal was x-rayed immediately after crushing

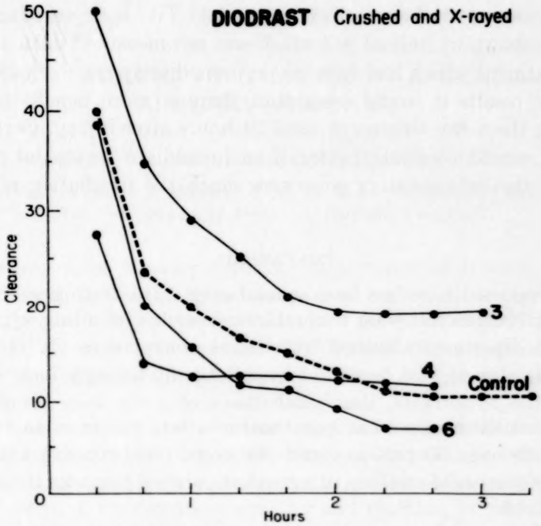


FIG. 12. *Diodrast and X-rayed Crush Injuries.* Animal #6 was irradiated 24 hours after crushing and measured 24 hours after irradiation. Detailed comparison in the text with animals #3 & #4 shows that there is apparent benefit in delaying x-ray treatment until 24 hours after injury.

but the pathology was allowed to develop for 48 hours before an injection was made into the crushed area. It is possible that the swelling and stasis of 48 hours overwhelmed the effect of the immediate x-ray treatment.

If the theory that x-ray treatment speeds up resolution of tissue fluid stasis is correct then it is reasonable to expect that animal #6 would have a higher rate of clearance than the control. The x-ray treatment was given 24 hours after crushing and was allowed to have effect for 24 hours before the isotope was injected.

The more rapid clearance rate of animal #8 which was not crushed but was measured 48 hours after x-ray treatment could also be explained on the grounds of the hyperemia known to be caused in normal tissues by irradiation. The same explanation would hold for animal #5 which was injected into an area 24 hours after it had been irradiated.

Animal #4 was given immediate x-ray treatment following the crushing injury and the injection was given 24 hours later. A more rapid clearance than the control might be expected and did occur.

Reviewing the three animals which were given x-ray treatment after crush injury it is seen that the greatest clearance occurred in animal #6 which was irradiated 24 hours after crushing but was not measured until the x-ray treatment had been allowed 24 hours in which to work (Figure 12). The middle rate of clearance was shown by animal #4 which was given immediate x-ray treatment and measured 24 hours after treatment. The least satisfactory rate of clearance was shown by animal #3 which was not measured until 48 hours after the x-ray treatment which had been given immediately after crushing.

From these results it would seem that there is more benefit to be derived from delaying the x-ray treatment until 24 hours after injury. Certainly such a time interval would correlate better than immediate treatment with the development of the inflammatory processes which the irradiation is supposed to affect.

CONCLUSION

The work reported here has been spread over 6 frustrating years. Many will know of the difficulties in trying to combine research with a busy clinical practice and of timed experiments ruined by clinical emergencies. T. H. Huxley has spoken of "the slaying of a beautiful hypothesis by an ugly fact" but it would appear that the hypothesis, that small doses of x-ray may be of help in the treatment of crush injuries, has been battered but not murdered. Clinical ex-experience with over 50 patients and the consistent experimental findings of accelerated resolution of swelling after radiation would appear to justify further work in this field.

Although the writer has every intention of continuing the work this report is published in the hope that others, with better facilities, will be encouraged by Dr. Moore's remarks to be better tenders of this somewhat rickety bridge. It would seem that the greatest problem is to find a clearance signal which is biologically inert and of particle size in the range of the molecular weight of the proteins present in crushed tissues. When this has been found the work should be repeated with better controls established over the many variables disclosed by the current experiments.

ACKNOWLEDGEMENTS

Dr. Walter Shanks of the London Hospital, England, originally supported this idea, advised me on many occasions, and treated the great majority of the patients. The costs of the laboratory work were borne by a grant from the College of Medicine Trust Fund and by the Departmental Research Fund. The work made use of the facilities in the University Radiation Research Laboratories of Dr. Titus Evans. It is a pleasure to record the constant help that he and his staff gave to a somewhat ignorant lodger. In particular I would like to thank Mr. Bruce Willis for his unfailing cooperation.

REFERENCE

1. Flatt, A. E. Treatment of crush injuries of the hand or foot by early irradiation. Proc. Roy. Soc. Med. **49:** 810–811, 1956.

THE TEACHING OF TRAUMA IN A GENERAL SURGERY PROGRAM

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Most of us are quite familiar with the importance of trauma as a leading cause of death and disability. If one needs convincing, all he need do is read the figures of the National Safety Council which show, for example, that in 1956 throughout the United States there were 95,000 deaths due to all accidents. The importance of careful and thorough training of those who are to take care of the victims of trauma must, then, be equally obvious.

Many of the deficiencies in the present day teaching of the management of trauma have been pointed out before but some of them might bear re-emphasis at this time. Some of these deficiencies spring from the nature of the disease and others from modern day concepts of practice and teaching in medicine.

Of course, trauma always occurs acutely and unexpectedly and often at the most unseemly hours of the day or night. Care of the injured patient must be carried out immediately and cannot wait for any schedule. Unfortunately, in too many teaching institutions the only one available at these odd hours is the intern who is at the beginning of his course of study.

If the injury is obviously grave the intern can usually get consultation from a senior resident or senior staff member soon, though crucial time may be lost in that short interval. On the other hand, the majority of cases of trauma are of such a minor nature that the intern feels that he does not want to bother his senior colleague for trivial matters and does not seek advice as often as he should. A considerable number of these "minor cases", unfortunately, are more important than is realized at the time and he may complete his emergency room assignment after a brief period without ever having the consequences of the inadequate or ill advised therapy of divided flexor tendons, avulsed skin and the like made apparent to him. The consequences of improper care in hand injuries, for example, are so obvious in terms of disability to the patient and economic loss as to require no further emphasis to this group. It is difficult to find the kind of supervision that provides ready consultation and advice for the junior member of the staff at the time when it will do him and his patient the most good, while he is taking care of everyday run-of-the-mill injuries.

Another consideration which has great influence on teaching in trauma is the currently popular sub-division of the management of the patient among specialists. Each one has his part to care for and the patient had best hope that the sum of the parts comes close to being a reasonable whole. That this may not prove to be true is only too obvious in certain circumstances. For example, one case of many similar ones known to the authors may be cited to illustrate this point. A patient brought into an emergency room in severe shock from an automobile accident was found to have one obvious and very severe injury which was reason enough to explain the shock. The "specialist" for this part was called by the emergency room nurse and promptly set about his work treating the conspicuous damage. The patient, unfortunately, died in the course of treatment from another serious, more urgent, and undiscovered injury.

This case is not cited to condemn specialists or specialties as the obvious benefits of specialism are too well known to gainsay, but examples of this type are seen too often to make us complacent about our present methods of teaching trauma, particularly as it relates to the management of the patient with multiple injuries. It is not the mere fact that surgeons are highly trained in one or another special field that is the root of the trouble, but rather that the tendency to promote a sharp division of labor in care of the patient and the tendency to criticise those men who step across the sharply, but sometimes arbitrarily, drawn specialty lines allows the patient as a whole to be neglected in the midst of a flurry of concern for his various parts.

Trauma is very often generalized and a multiplicity of injuries is commonplace in these days of high speed vehicles and machines. Anyone who undertakes to treat any type of trauma should have basic grounding and broad interests in all aspects of trauma and its physiological, biochemical and pathological effects. He should have a thorough knowledge of the mechanisms, effects, and management of shock and an appreciation of the interrelationship of multiple organ system involvement. It is not enough that the "doctor for the first part" tell the "doctor for the second part" (deemed more important at this moment) to ask that he (the former) be notified when the latter has completed his work. Such decisions of timing, priority of treatment, and the like often require the closest consultation between both specialists but, furthermore, each should have enough appreciation of the other's field and the influence of both conditions under question on the patient as an organic whole that he will be able to contribute his part of management to the maximal benefit of the patient. In addition, the responsibility for management of each patient as a whole must reside in one individual regardless of how much help or how many consultants that responsible individual may have to assist him.

This paper will outline a program of teaching of trauma which has been in operation for a number of years in which maximum use of clinical material and teaching facilities is attempted. Several of the teaching devices used in this program will be described.

It should be noted that the general surgery residency in this hospital is based on the traditional concept of the Halsted type residency in which the responsibility of each member of the staff in teaching the members junior to him is reciprocated by the responsibility of the junior to the senior in the care of the patient and the operation of the clinical service.

The residency is a "parallel" one with a five year program from which ordinarily three men graduate each year. The accompanying table (Table I) shows the rotation of residents throughout the whole of the residency. The three senior

TABLE I

Resident's Rotation

	4 Months	4 Months	4 Months
1st yr.	Jr. Asst. Resident Service A	Jr. Asst. Resident Service B	Jr. Asst. Resident Service C
2nd yr.	Admissions Department	Outpatient Department	Specialty Service
3rd yr.	Sr. Asst. Resident Service A	Sr. Asst. Resident Service B	Sr. Asst. Resident Service C
4th yr.		Surgical Laboratory Surgical Laboratory Teaching Resident	
5th yr.	Chief Resident Service A	Chief Resident Service B	Chief Resident Service C

residents spend equal terms on each of the three major services. Service A covers female general surgery including fractures and proctology. Service B covers male general surgery also including fractures and proctology. Service C covers chest and cardiac surgery as well as pediatric surgery and surgical patients in the psychiatric building.

Two residents are assigned to the surgical laboratory for the fourth year of residency. The third resident in his fourth year serves as "teaching resident" in which capacity he fills the role of administrative chief resident and acts as coordinator of the teaching program. In addition, he acts as surgical consultant to the other services in the hospital.

During the second year each resident spends four months divided between orthopedics and neurosurgery and during this assignment works directly under the attending neuro-surgeon as there is no other resident on this service at present. During the calendar year of 1958 a total of 94 patients with head injuries were admitted to the hospital and cared for by the residents on this service.

This is a municipal hospital and serves largely a medically indigent group of patients many of whom have not been examined by a physician before they present themselves at the hospital for treatment. For this reason, all patients admitted to the hospital are examined by the admitting officer in the Admissions Department. In addition, the Admissions Department serves as the Emergency Room.

The admitting officer role is filled by the surgical assistant resident assigned full time to the Admissions Department or the full time assistant resident in internal medicine assigned to this department. The surgical assistant resident is in charge from noon until 9 a.m. and the medical assistant resident the remaining three hours from 9 a.m. until noon each day.

The assistant resident in charge of the Admissions Department is responsible for seeing each patient, calling consultants if needed, and making sure that the patient is treated and/or admitted to the appropriate service. This means that he sees each patient presenting himself at the Admissions Department whether the patient needs admission or only ambulatory or first aid care. The only exception to this policy is the obstetrical patient in active labor. This patient is admitted directly to the labor rooms without delay.

Facilities are available in or immediately adjacent to the Admissions Department for complete work-up of any type of emergency clinical condition. This work-up may include x-rays, electrocardiograms, hematology or urine studies. The blood bank is a part of this suite of rooms and, therefore, blood is readily available for use in acute emergencies.

The extent of work-up of each patient depends on the need as seen by the examining physician. However, when the work load permits, both the medical and surgical assistant resident in the Admissions Department as a minimum work-up take complete histories and do physical examinations on all patients admitted to their respective services.

In addition to the assistant resident whose daytime assignment is to the Admissions Department, he and the two residents assigned to OPD and the surgical specialties rotate to provide night time coverage of the Admissions Department, so that each serves every third night. One or two interns are assigned for a one month period to this Department.

During the school year each third year student is assigned for one full week to the Admissions Department for daytime duty and two fourth year students are assigned there each evening so that the latter serve about every fourth evening throughout their eight week tour in the Surgery Department.

For acute surgical conditions the surgical assistant resident in admissions carries out whatever work-up is necessary, supervises or carries out necessary resuscitative or preliminary care and calls his chief resident. If the patient goes directly to the operating room from the Admissions Department, the assistant resident who has provided care thus far takes part in the operation and is relieved of his admissions duties while in the operating room by one of the other assistant residents.

This means that all trauma patients are seen initially by a surgical assistant resident who is responsible for the proper evaluation of such cases. For patients, who can be cared for without admission, he performs the necessary treatment personally or supervises the intern or student in carrying out this care. Where other specialists' services are needed, the surgical resident sees that the appropriate consultant is called and helps him with care of the specialty service when only a special problem is involved. However, in cases of severe mixed trauma all such patients are admitted to the general surgery service and the other specialists serve as consultants with final responsibility resting in the hands of the general surgeon until such time as the patient's problems may resolve into those of one particular field or another at which time the patients are transferred entirely to the care of the appropriate specialty service.

Fracture patients are admitted on alternate months to the orthopedic service and general surgery fracture service. Hence, on the even months of the year after initial examination and x-ray of the patient, the admitting resident calls the orthopedic consultant and turns the care of the patient over to the orthopedic resident or assists him with the care of the patient if it is carried out in the Admissions Department.

In the case of patients with injuries falling into the field of those services which have organized residencies (orthopedics, urology, ophthalmology, gynecology), the surgical resident performs the initial examination and may watch or assist the specialist in the care. In the case of injuries which fall into the scope of the other surgical specialties (neuro-surgery, plastic surgery, proctology, otorhinolaryngology) in each of which consultants are available but no organized residency exists, the surgical resident helps to carry out treatment directly under the attending surgical specialist.

All cases of trauma are seen, then, by a surgical resident in his second year of training. He may allow the intern or clinical clerk to carry out treatment on minor cases under his supervision. If the assistant resident deems the case more severe, he calls for consultation from his immediate superior—the chief resident on the service to which the patient normally would be admitted. If this resident is not available (because of operating room or other responsibilities) the teaching resident is called, since he is the administrative chief resident and not likely to be operating, he usually can be reached within a short time. At night the senior resident on call is summoned who in turn seeks the appropriate attending general surgeon for advice and consultation. During the night time and week-end hours, a single attending surgeon is assigned to provide consultation on all emergency cases.

In recent years, a system has been introduced which we believe is rather unique and of great benefit in providing instruction and consultation in one of the areas where teaching and care of trauma is weakest, namely, in the so-called minor cases. The same device serves to cover another deficit in the care of certain types of patients. A number of patients with various types of injuries acquired at work present themselves at the hospital Emergency Room for care. They come from neighborhood factories and employers whose business is too small to have regular medical care programs and who use the nearby hospital because of its convenience. According to the New York State Compensation Law these patients may be rendered first aid in a hospital Emergency Room, but they must subsequently be under the care of a physician authorized by the State Compensation Board to treat such cases. These patients, if they do not require hospitalization, are referred to family physicians for follow-up care. In the past, those patients who had no regular physician and who requested referral were sent to a staff physician for care. These latter patients were lost to the resident staff for the most valuable part of their course of management from the point of view of teaching, i.e. the follow-up period of care. Moreover, many of the patients were unhappy because they preferred to see the individual who began treatment because of their (the patients) belief in the importance of continuity of follow-up.

Attending general surgeons are now assigned in rotation for a two month period to the Ambulatory Surgery Service. The attending surgeon on this service visits the Admissions Department for one to two hours daily except Sundays.

At this time he sees all those compensation patients who request assignment to a staff physician's care, as well as others who request private care and wish a staff surgeon to provide this care. In addition, the surgical assistant resident in charge of Admissions brings to this Clinic ambulatory service patients who have minor surgical problems for which the attending surgeon's advice and consultation is desired.

Care of the patients in this Clinic is carried out by the resident, interns, and students under the direct observation and supervision of the attending surgeon, who may advise and teach at this time. This has turned out to be a most valuable teaching session for the management of minor trauma and other minor surgical problems. Interns and students have been particularly enthusiastic.

This Clinic arrangement has three distinct advantages. It prevents the loss to house staff teaching of a considerable number of valuable teaching cases. It provides the services of an experienced surgical teacher at the time it is most needed; (i.e. when the patient is present) for answering questions of students, consulting with the resident staff on problems, reviewing methods and techniques, and teaching the management of those small but common and really important matters in the care of everyday trauma cases. Finally, a group of patients, whose care often is much less than ideal, receives the best of care.

An indication of the extent to which the teaching of trauma has benefited from this Clinic may be gained by referring to the accompanying table (Table II) which summarizes the experience of this Clinic for one year and shows the total number of patients seen as well as the totals in certain exemplary major categories of injuries. In essence, this represents the teaching material used in a daily class in practical care of minor trauma.

Patients with injuries requiring hospitalization to be cared for by the General Surgery Service are admitted to the services of the regular attending surgeons except for fracture patients, who are, on the odd months of the year, admitted to the Fracture Service to which attending surgeons are assigned for four month periods.

In addition to rounds by the attending surgeons and presentation of interesting trauma cases on Grand Rounds, one of the most important teaching sessions is the Trauma Conference which meets for one and one-half hours weekly and at

TABLE II

Patients Cared for in Special Ambulatory Surgery Clinic in One Year

Category of Injuries	Number
Fracture, Dislocation and Sprain	388
Lacerations	494
Bites	109
Puncture Wounds	81
Foreign Bodies	85
Others	1288
Total	2445

TABLE III

General Surgery Service, Meyer Memorial Hospital, 1958
Summary of Trauma Material, Certain Categories

Category	Number
Admitted to the Hospital	
Head Injuries	94
Chest Trauma	22
Abdominal Trauma	12
Major Soft Tissue Injury	56
Tendon and Nerve Injury	23
Fractures	142
Burns	27
Not Admitted to the Hospital	
All Ambulatory Emergency Patients	10,173
Fractures	352
Lacerations sutured	1,132

which four to six patients are presented and discussed. Attending surgeons from General Surgery, Orthopedics, Plastic Surgery, and occasionally Neuro-surgery are present as well as all surgical residents, interns, and third and fourth year medical students assigned to surgery. It is a most lively conference, attendance is always excellent, and during the course of the academic year examples of all types of trauma and much of the available clinical material are presented and discussed. For one-half hour after the formal conference, the students are taken in a group by an individual instructor away from the excitement of the sometimes heated discussion of the conference so that they may have questions answered that might have arisen and not been answered during general discussion.

Trauma cases of unusual interest are presented and discussed at the weekly surgery staff conferences from time to time.

Since the follow-up care of fractures is of such importance in teaching, all residents are encouraged to attend the weekly Fracture Clinic and about one-third are able to do this. The attending surgeon on the Ambulatory Surgery Service attends this Clinic as does the Associate Director of Surgery, who is also the official charged with responsibilitity for the supervision of the Admissions Department.*

Though the accompanying table, (Table III) which lists the number of patients seen in one year in certain trauma categories, demonstrates that the trauma service in this hospital is not extremely large—it does show that a good variety of cases is seen. Every effort is made to use all clinical material available and all aspects of the care of trauma are emphasized in teaching.

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* It should be noted that the Associate Director of Surgery visits the Admissions Department one or more times daily and since he is a full time member of the staff, is readily available for consultation by the resident staff in emergencies when the responsible attending on call may not be readily contacted.

SUMMARY

A program of trauma teaching is described which provides for teaching at all student levels from third year medical student to senior surgical resident and features the following points:

1. All trauma patients are seen initially by an experienced surgical resident.
2. Primary responsibility for initial evaluation of the trauma patient and for management of cases of multiple trauma resides in the general surgical resident.
3. There is adequate supervision and consultation by attending surgeons for minor as well as major trauma night and day.
4. Maximum use of all clinical trauma material is made for teaching purposes.

REFERENCE

1. National Safety Council. *Accident Facts*, Chicago, Illinois, 1957.

MYOSITIS, FASCIITIS, FIBROSITIS, MYOFASCIITIS—MEDICAL OR LEGAL

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Anyone reviewing recent files of personal injury or medical legal cases cannot fail to be impressed with the frequent appearance of the terms myositis, fasciitis or fibrositis, singly or in combination, used to explain the presence of persistent pain or tenderness in soft tissue at or near the site of non-penetrating injury. Similar use of these terms is frequently made by physicians on the witness stand with the implication that a bruise or sprain has in some way caused a self-perpetuating chronic inflammatory reaction: hence, the suffix, "itis".

The variety of diagnostic terms used in a series of sixty personal injury cases was reviewed (1). Fourteen of these are shown in Table I. In many of these patients the diagnosis was made on the basis of a single examination long after the alleged injury.

Since the use of these terms connotes the presence of an inflammatory process, an inquiry as to their propriety is something more than academic exercise in semantics. If the disability for which compensation is claimed is not due to a chronic state of inflammation, diagnostic terms such as these are not only inaccurate, but may be misleading in that they suggest a more direct relationship to an antecedent trauma than may be warranted by the facts.

It is true, of course, that crushing or laceration of soft tissue with devitalization or the accumulation of extravasated blood in it may set up an aseptic inflammatory reaction. It is also a fact that such a region of soft tissue injury may constitute for a relatively brief period of time a locus of diminished resistance to infection.

When an inflammation-inciting mechanical injury is sustained, it is usually, if not invariably, associated with definite and almost immediate evidence of disruptive damage to and hemorrhage into the traumatized region. In the absence of infection such an inflammatory reaction usually persists no longer than is required for the absorption of the dead tissue and the extravasated blood. If pain, tenderness, muscle spasm or limitation of motion at the site of injury weeks or months after its occurrence is to be attributed to inflammation, such a conclusion should be based on the knowledge either that a biopsy of that particular lesion does disclose inflammatory reaction, or that biopsies of lesions similar to the one in question usually disclose evidence of inflammation.

The correctness of a clinical diagnosis of inflammation depends on the degree of certainty that exists that the presence of inflammation would be confirmed if the affected tissue were subjected to microscopic examination.

Read before the Twentieth Annual Session of The American Association for the Surgery of Trauma, Coronado, California, October 5–7, 1960.

TABLE I

Diagnostic Terminology from Legal Reports

1. "Traumatic myofasciitis of back"
2. "Myositis cervical spine"
3. "Alleged trauma cervical spine with marked myositis"
4. "Lumbo-sacral back sprain with associated myositis"
5. "Fasciitis, spine, with arthritic diathesis, traumatic and metabolic"
6. "Myositis arthritis"
7. "Myositis of lumbar spine"
8. "Myositis of neck"
9. "Myositis of left musculature"
10. "Myofasciitis of both thighs"
11. "Fibromyositis of left elbow"
12. "Trauma of cervical spine resulting in myositis of structures"
13. "Myositis of back"
14. "Fibrositis"

Because of these considerations, an effort was made to collect such facts as might be available regarding correctness of these terms (myositis, fasciitis and fibrositis) as they are commonly used to designate certain clinical sequels of non-penetrating soft tissue injury.

A questionnaire requesting the following data was sent to 200 surgeons throughout the United States who are prominently associated with the diagnoses and treatment of traumatic injuries. 110 replies were received.

1. "Do you use the terms myositis, fasciitis, fibrositis and myofasciitis in describing acute or chronic painful areas that persist following trauma?"

38 percent of those replying did not use any of the above terms; 18 percent used all, and 44 percent used some of them. Table II represents the general spread of all replies to this question.

2. "If you use these terms, have you had occasion to biopsy any areas so diagnosed, clinically, and was your clinical diagnosis substantiated by the pathological findings?"

81 percent of those who replied had not biopsied any such lesions; 19 percent had biopsied one or more. Of these, only two reported the finding of pathological evidence of inflammation in the biopsy material. One remarked that he had found mild edema and lymphocytic infiltration on a number of occasions and another described localized infiltration with lymphocytes in an unspecified number of cases.

3. "Do you think that any of the terms mentioned in question one are correctly descriptive of localized persistent post-traumatic pain?"

54 percent replied in the negative; 37 percent said yes. In the other nine percent the replies were equivocal.

4. "If you do not use the terms, myositis, fasciitis, fibrositis or myofasciitis, what diagnostic terms do you use to describe areas or regions of pain, or tenderness, in soft tissue persisting after trauma?"

Approximately 25 per cent (27 of the 110) did not answer this question. Some

TABLE II

Distribution—Diagnostic Terms—Questionnaire

(110 answering)

	YES	NO
Myositis	63	47
Fasciitis	35	75
Fibrositis	44	66
Myofasciitis	33	77

surgeons used more than one diagnosis. The terms myositis and myofasciitis appeared even though the question specifically requested alternative terminology. The diagnoses suggested are listed in Table III.

Because the information secured from the questionnaire was not conclusive as to whether or not a persistent state of chronic inflammation is likely to be the cause of the various combinations of pain, tenderness, muscle spasm and limitation of motion that are so frequently the basis of claims for compensation after non-penetrating soft tissue trauma, it was decided to see what might be learned from another potential source of information, namely, directors of pathology laboratories where large volumes of biopsy material are examined.

An inquiry regarding the pathologic changes observed in these post-traumatic clinical entities was first directed to the Armed Forces Institute of Pathology, this institution being undoubtedly the richest repository in the world of pathological material dealing with trauma. Other than myositis ossificans and possibly pseudosarcomatous nodular fasciitis, no examples of chronic myositis, fasciitis or fibrositis presumably due to non-penetrating trauma were recorded. The same situation prevailed in the files of the pathology departments of two large general hospitals in Cleveland (University Hospitals and St. Luke's Hospital) where, for many decades, thousands of surgical specimens and biopsies of all kinds have been examined.

The next avenue of inquiry was the medical literature. Although the literature contains a number of references to the inflammatory basis of the conditions under discussion, none was found in which the presence of inflammation was claimed to have been established by histologic examination of biopsy material.

So far as could be determined, the concept of post-traumatic myositis, fasciitis and fibrositis as causes of protracted disability following non-penetrating soft tissue injury is based entirely on theoretical considerations.

Williamson (4) concluded that a force great enough to rupture a vessel is usually great enough to injure the underlying muscle and attributed the ensuing spasm to a reaction to the chemical irritation.

Stoll (3) believed that abnormal reflexes are likely to become established during the periods of temporary immobilization. He added that pain stimuli probably originate from a "localized fascial inflammatory reaction."

Steindler (2) states that fascial adhesions form at the sites of disruptive injury and that such adhesions commonly cause painful restriction of motion.

TABLE III

Suggested Diagnostic Terminology—Questionnaire

Suggested Diagnostic Term	Number of Times Used
No Answer	27 of the 110
Contusion	22
Bruise	4
Myalgia	5
Myositis	10
Myofasciitis	1
Myofibrosis	1
Scar or Cicatrix	8
Strain	15
Sprain	7
Hematoma	17
Others: "Charley Horse," fat necrosis, causalgia, Sudeck's atrophy, muscle laceration, sore muscle.	

CONCLUSION

It is a fact that some persons do suffer pain and limitation of motion at sites of non-penetrating injury for weeks or months thereafter. Whatever the cause of such a disability may be, there seems to be very little evidence to support the supposition that chronic inflammation is one of them. In view of this, it would be better to characterize the disorder by its clinical manifestations (pain, tenderness, muscle spasm or limitation of motion) rather than to misuse terms with such precise implications as those ending in "itis".

Enough obstacles exist in settling personal injury cases in optimal circumstances without embellishing alleged injuries with inappropriate designations.

REFERENCES

1. Claims Research Bureau of The Association of American Railroads—Personal Communication.
2. Steindler, A. *Lectures on the Interpretation of Pain in Orthopedic Practice.* Charles C Thomas, Springfield, Ill., 1959.
3. Stoll, B. A. X-ray therapy in post-traumatic arthritis, para-arthritis and fasciitis. M. J. Australia, **1:** 868–873, 1957.
4. Williamson, P. Myofascial disease. Am. Pract. & Digest Treat., **9:** 1225–1229, 1958.

DISCUSSION

Dr. Donald M. Glover (Cleveland, Ohio): Dr. Brown and Dr. Moritz have served us well by bringing into focus one of the perplexing problems in terminology. I am in complete agreement with them that the terms in question are improper and merely lead to confusion. Perhaps we have other terms which need further clarification, such as synovitis, bursitis and the like.

How did we get ourselves into this pocket?

Review of the process of healing of contusions, tears and strains of muscle, ligament or joint capsule remind us that during the early stage, which lasts a matter of hours or days, there are hemorrhage and release of products of muscle destruction into the tissues, which cause systemic evidence of shock in some degree and a secondary adrenal steroid response. This stage is also characterized by local pain and muscle spasm. The second stage is that of resorption of blood products which lasts for days and sometimes weeks, during which motion is painful and muscle atrophy is likely to occur with injudicious immobilization.

During the final stage of repair, with the reorganization of adult collaeous tissue, painless function should be resumed. But the establishment of sensory nerve endings in all insults to tissue, either accidental or intentional, is somewhat unpredictable. At first there is anesthesia, then hyperesthesia or paresthesia, and finally normal sensation. But it is well known that this process may be altered by the impaired circulation from many factors which have to do with treatment, particularly muscle inactivity, and continued painful responses may be the long-continued result of inadequate treatment early and too much treatment later. True inflammatory process is not present, however, in the stage of these processes in which the terms being discussed are employed.

Perhaps while we are trying to clear up our terminology in this confusing area we should also emphasize the intelligent treatment of the injuries to which we are alluding, in order to favor rapid healing, adequate vascularization and early resumption of painless function; and also to encourage better psychological indoctrination of the doctor and the patient, in order that our legal friends may not capitalize our confusion to the detriment of the patient and the public.

DR. KENT LOUIS BROWN (Closing) (Cleveland, Ohio): I would like to thank Dr. Glover for his comments, and also those of you who answered the questionnaire.

As many of you know, there was much more material in the questionnaire than has been covered here today. Those answers were most interesting and will be reported upon later.

I would like to mention one thing brought to my attention by several physicians and lawyers who were kind enough to review this paper. It was their opinion that at least some of the difficulties we have discussed could be avoided if the physician who examines the patient at the time of the initial trauma would take a complete and accurate history and describe and report the physical findings in detail.

NONOPERATIVE TREATMENT OF THE FRACTURED TIBIA BY IMMEDIATE WEIGHT BEARING

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INTRODUCTION

Our method of treating the fractured tibia arose from the simple premise that the severe complications resulting from surgery could only be eliminated by foregoing open reduction. We were then looking for an approach which should fulfill the following criteria as well as possible. The method should be applicable to all fractures of the tibia without exception, be simple and easy to learn and lead to early union and optimal functional rehabilitation. We have settled on treatment of the fractured tibia by immobilization in a near skin-tight cast with the knee held in full extension and with immediate weight bearing. The only exceptions in this management were cases with associated injury or disease which prevented immediate weight bearing. In those cases, weight bearing was started as early as possible. We have now practiced this method for over ten years and have satisfied ourselves that it meets the criteria outlined above.

MATERIAL

The method was initiated in July 1950 at the 98th General Hospital in Munich, Germany. Since then all fractures of the tibia have been treated by this method without any exceptions. However, since the adoption of this new policy constitutes quite a radical departure from the methods previously used, it required several months to familiarize the personnel with this new technique. During the initial period, a small number of patients were set up in skeletal traction upon arrival at the hospital. Treatment was then changed to the current method immediately. This method was then introduced at Letterman General Hospital in 1954, at Martin Army Hospital in 1958, at Walter Reed General Hospital in 1959, and at Brooke General Hospital in 1960. Our end result studies with the composite of several individual studies made at the various hospitals are summarized in Table I.

Read before the Twentieth Annual Session of The American Association for the Surgery of Trauma, Coronado, California, October 5–7, 1960.

The fractionated evaluation of the material in our five reviews above has the obvious disadvantage of some lack of uniformity in regard to consolidating the entire series. However, from each separate evaluation we have learned the need for additional considerations which had not been included in the previous one and, therefore, were included in each subsequent series.

TABLE I

Hospital	Time	Reviewer	No. of Cases
98th General Hospital Munich, Germany	1950	Dr. F. W. Coggins	100
Letterman General Hospital San Francisco, Calif.	Jan. 1954 to Dec. 1957	Major R. M. Hall	60
Walter Reed General Hospital Washington, D. C.	1959	Lt. Col. C. W. Metz	10
Martin Army Hospital Fort Benning, Georgia	1958–1960	Lt. Col. Philip Deffer	27
Brooke General Hospital Fort Sam Houston, Texas	Aug. 1960 to Present	Capt. Egon V. Johnson	10
Total			207

TABLE II

Type of Fracture	Per Cent of Cases
Simple	70
Compound	30
Fractures of the tibia alone	16
Fractures of tibia and fibula	84
Fracture of both bones of leg associated with other injuries or co-existing diseases	17
Transverse fractures with displacement	8
All other types of fractures	92

The breakdown of the type of fracture summarized in Table II is essential for the understanding of our description of technique and discussion of results. For instance, transverse fractures with displacement are treated by manipulation under spinal anesthesia, while all other types of tibial fractures are treated by alignment only and often without anesthesia. The isolated fractures of the tibia without associated fracture of the fibula furnish the group from which some patients were selected for osteotomy of the fibula. Amongst the 17 per cent of fractures which were associated with other injuries were those patients in which ambulation had to be delayed until they were sufficiently recovered and who were thus also slower in healing.

METHOD

Reduction: For all fractures of the tibia, with the exception of transverse fractures, we believe that slight shortening enhances early union. Our method

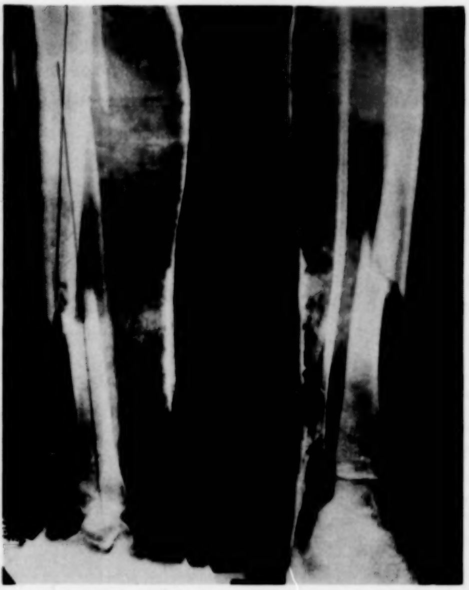

FIG. 1a. Compound fracture in 19-year-old female incurred in automobile accident. Compound wound locally cleaned and cast applied. Cast subsequently wedged to correct angulation. The intersection of the axis determines the pivot for wedging of the cast.

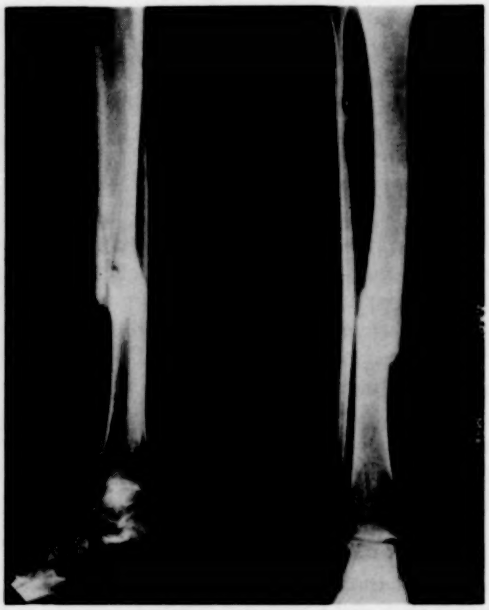

FIG. 1b. Angulation corrected by wedging and fracture healed in 19½ weeks

of reduction, therefore, consists of placing the patient in the sitting position and permitting gravity, occasionally enhanced by gentle manual pull, to gain the desired length. A short leg cast is then applied, protecting the skin with one layer of orthopaedic paper or Webril. As soon as the short leg cast is hardened the patient is placed on his back; care is taken to avoid angulation of the fracture by supporting the short leg cast both under the heel and under the fracture site. The cast is then extended to the groin with the knee held in full extension. Meticulous care is taken to avoid rotational deformity, and any angulation is corrected by wedging of the cast, determining the pivot of the wedge by intersection of the long axis of the fragments (Fig. 1a & b). The ankle is usually casted in slight equinus position since right angle position of the ankle tends to produce recurvatum at the fracture site. This pertains particularly to fractures of the lower third of the tibia. In general, it is possible to carry out the initial reduction without anesthesia. Whenever this causes discomfort to the patient, local anesthesia at the fracture site is preferred. Wedging of the cast never requires anesthesia. The shortening accepted in fresh fractures is generally less than 3/8 inch. In fractures received within a few weeks after the injury with

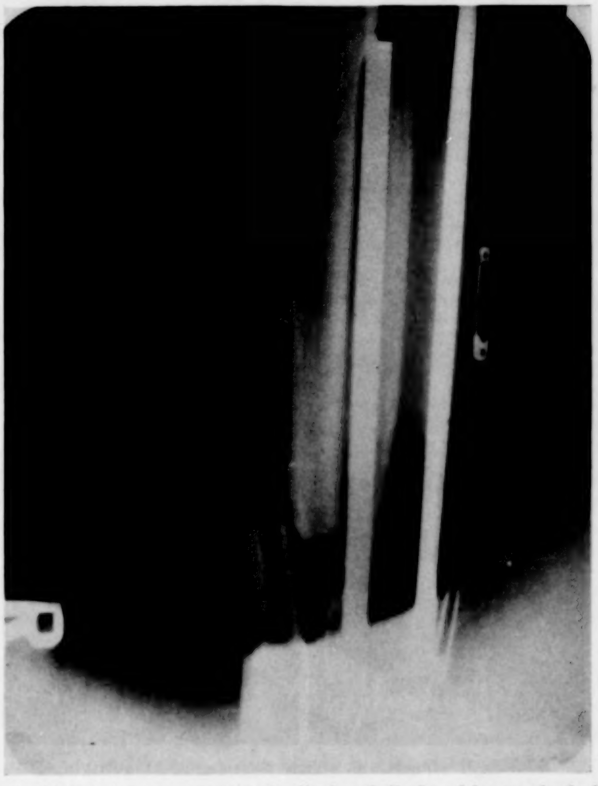

FIG. 2a. Simple fracture completely displaced. Reduced by manipulation

shortening up to ¾ inch, no further attempt to gain length is made. Likewise, in severely comminuted and severely compounded fractures ¾ inch shortening is accepted without hesitation.

Completely displaced transverse fractures of the tibia were encountered in 8 per cent of our patients (Table II). In this type of fracture we prefer manipulation by angulation of the fracture under spinal anesthesia. Anatomical reduction was possible by this method in all except two cases, both of whom were treated previously at other installations. One was a simple fracture which occurred ten days previously; the other was a compound fracture in which initially an attempt in obtaining primary closure by shifting of skin flaps had failed. This patient was treated with split thickness skin graft and no attempt was made at reduction (Fig. 2a & b).

It has been our primary axiom to avoid open reduction as the only means of forestalling the occasional severe complications of surgery. Even healing in deformity would be preferable to such complications (Figs. 3a, b, c).

We are convinced that the use of traction tends to delay healing and we feel that it too can be avoided, although our series includes 15 cases in which

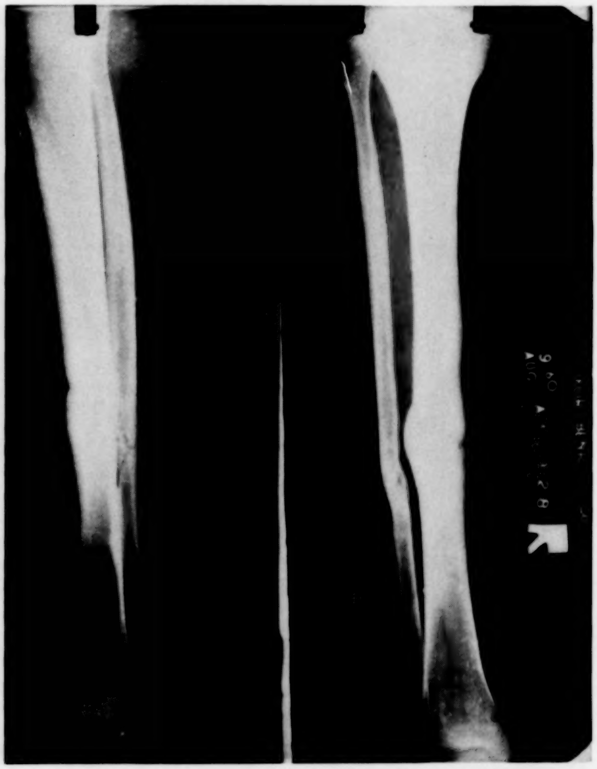

FIG. 2b. Healing in anatomical position eight months later

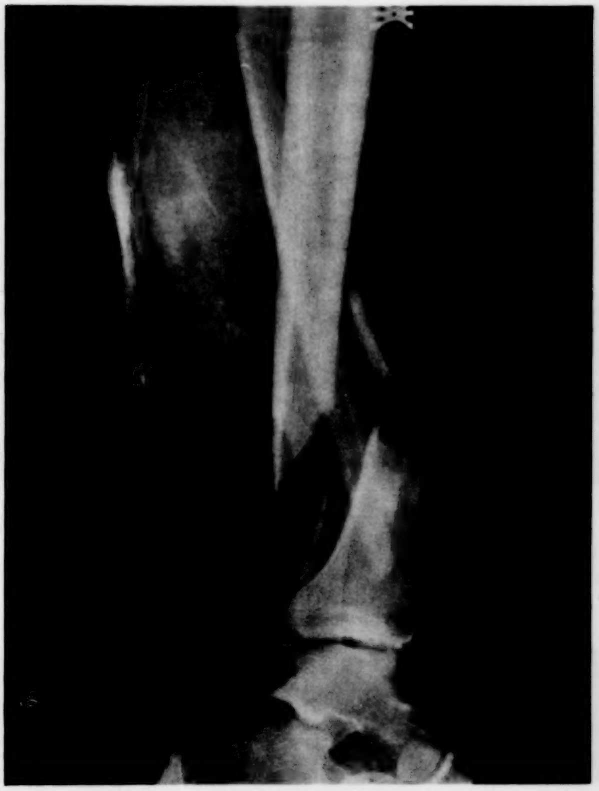

FIG. 3a. Severe compound fracture which was originally reduced but the position was lost in secondary skin grafting.

traction was initially used before transfer to our hospital. Eight cases fell into the first 6 months of our series when we were still feeling our way along, and traction was used for 10 days or less before applying our weight bearing casts. Six cases of the Letterman series had been treated initially in traction before being transferred to our Service, but were switched to our weight bearing regime immediately after transfer. In one 83-year old patient who had a segmental fracture of the tibia with massive swelling, multiple tension blisters of the skin, and precarious circulation we used traction for three weeks for the purpose of facilitating the use of local hypothermia before switching him to our weight bearing regime.

Extended Position of the Knee: It is generally believed necessary to immobilize the knee in some degree of flexion in order to control rotational alignment of the fragments. In our experience, this was not necessary since we did not observe secondary rotational deformity in any of our cases. We prefer extension of the

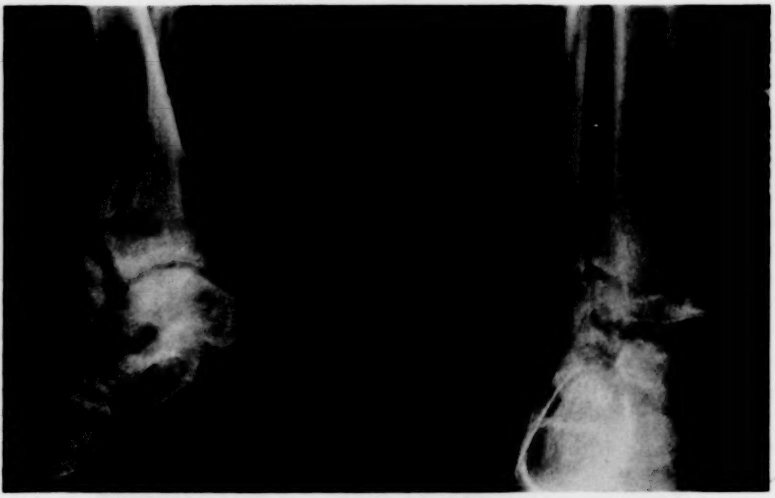

Fig. 3b. The situation was further complicated by an unreduced dislocation fracture of the talus on the other foot. The patient came under our management 4 weeks after injury. The injured tibia was draining and completely loose. The fractured talus was first mobilized in bed and then weight bearing was started protecting each extremity with the opposite crutch.

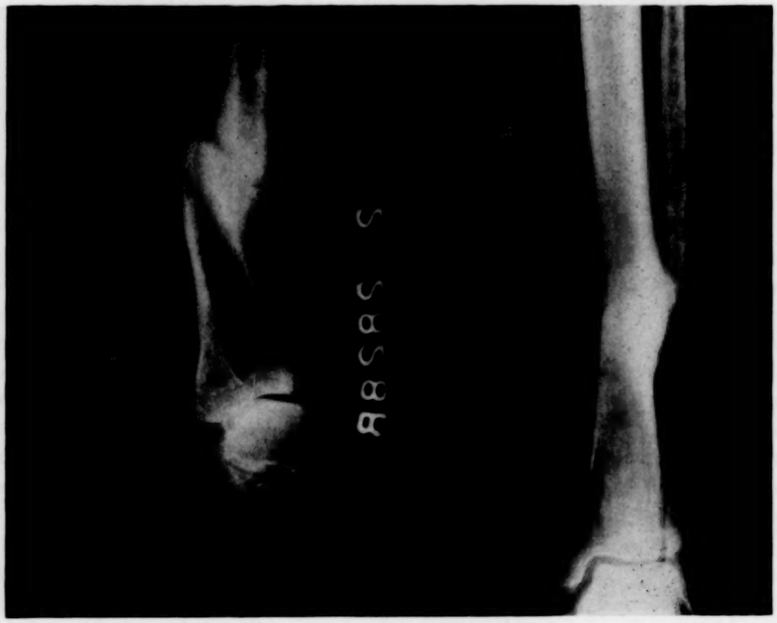

Fig. 3c. Seven months after the injury the patient had solid union of the tibia, no complaints associated with his mangled talus, and returned to limited military duty.

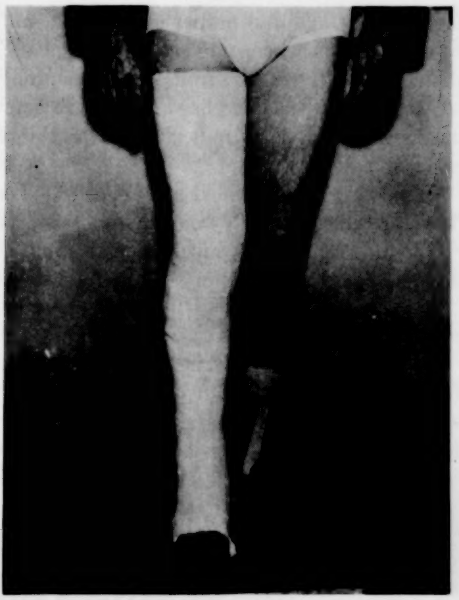

Fig. 4a. Type of cast used in treatment of fracture of the tibia

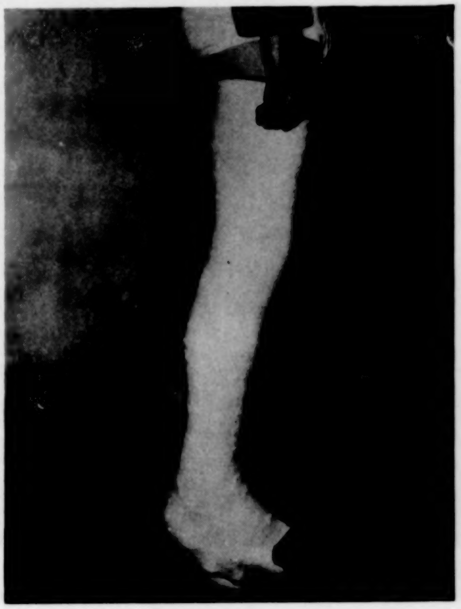

Fig. 4b. Extension of the knee is important. The ligaments of the knee shorten when the knee is casted in flexion. This same principle is well recognized in the MP joints of the hand.

knee for two reasons—1) to facilitate proper gait habits, and 2) full extension of the knee is the only position which prevents shrinkage of the ligaments and thus facilitates mobilization after release from immobilization. The same principle in regard to the MP joints of the hand has long been recognized and accepted, but in the hand the ligaments are tight in flexion, and in the knee they are tight in extension (Figs. 4a & b).

Rehabilitation: Where we have simplified and relaxed our criteria and efforts for reduction, we have placed considerably more emphasis on supervised rehabilitation. Thus, the amount of time and supervision devoted to each individual patient considerably exceeds time and effort devoted in other methods of treatment.

Immediate Ambulation: This was not a measure that we had decided to impose upon our patients, but from observing patients who had started immediate weight bearing on their own without discomfort and without subsequent loss of position, we learned that this approach could not only be tolerated but seemed to have definite advantages. We believe that the functional stimulation through weight bearing may well contribute to the rapid and consistent con-

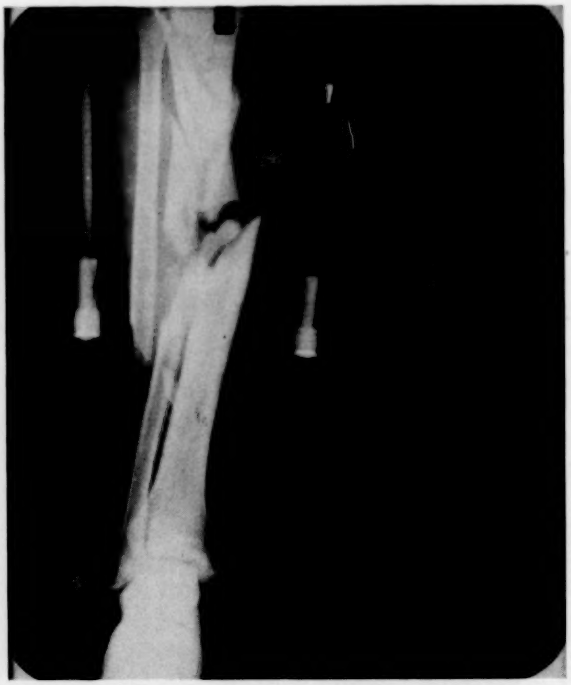

FIG. 5a. This injury resulted from a helicopter crash with the blades chewing the leg. A fracture of the forearm prevented crutch walking and this was therefore delayed for two months.

solidation observed in our cases. But it may well be that other factors in our approach may be equally as important. There is no question, however, that ambulation prevents the amount of swelling and joint stiffness, as observed in those patients with plaster immobilization who are permitted crutch walking with the leg dangling.

During the first day while the plaster is hardening the patient is prepared for weight bearing by practicing active elevation of the casted extremity, and also with Buerger-Allen exercises to improve his motor control. The next day the patient is given a pair of crutches which are used in conjunction with a walking cast. The patient is instructed to distribute the weight between his crutches and the walking cast in such a manner that he can ambulate without pain; but normal gait, rhythm and stride are insisted upon. Walking in the first days constitutes simply a therapeutic exercise and in locomotion at will. From the first day on, the amount of walking, as well as weight borne on the cast, is increased as the patient tolerates it, the limiting factors being pain or develop-

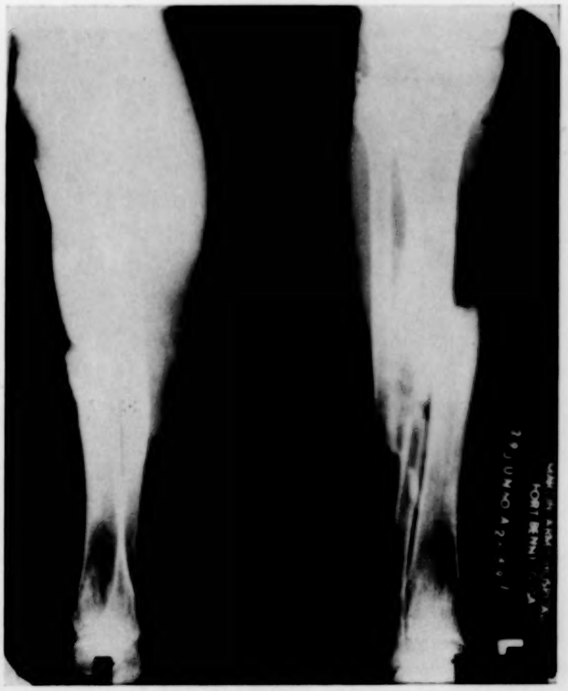

Fig. 5b. The initial surgeon had attempted to convert the open fracture into a closed one by shifting of skin flaps which sloughed and the fracture became infected. The supportive bone grafts through a posterior approach were successful in spite of the fact that the drainage had not completely subsided at that time. One year after the injury the patient returned to duty.

ment of swelling. Many patients discard their crutches spontaneously within a few weeks. During the first two years of this management we permitted our patients to return to limited military duty at this point, but since we observed that the patients who were left to their own care tended to return with swollen legs and required longer period of treatment than the ones that were kept in the hospital throughout the entire course we have discarded that policy. It is preferable not to change the first cast for eight weeks if possible, since many fractures are consolidated by this time. Those with earlier cast changes tend to heal slower.

Exceptions from immediate ambulation had to be made in 17 per cent of our patients (Table II) where other injuries or co-existing diseases prevented immediate ambulation. These were the patients with associated fractures of the femur treated by traction, or patients with co-existing fractures of the upper extremities preventing the use of crutches. Except for the delay in weight bearing caused by these associated conditions the treatment was identical and weight bearing was instituted at the earliest time possible (Figs. 5a & b).

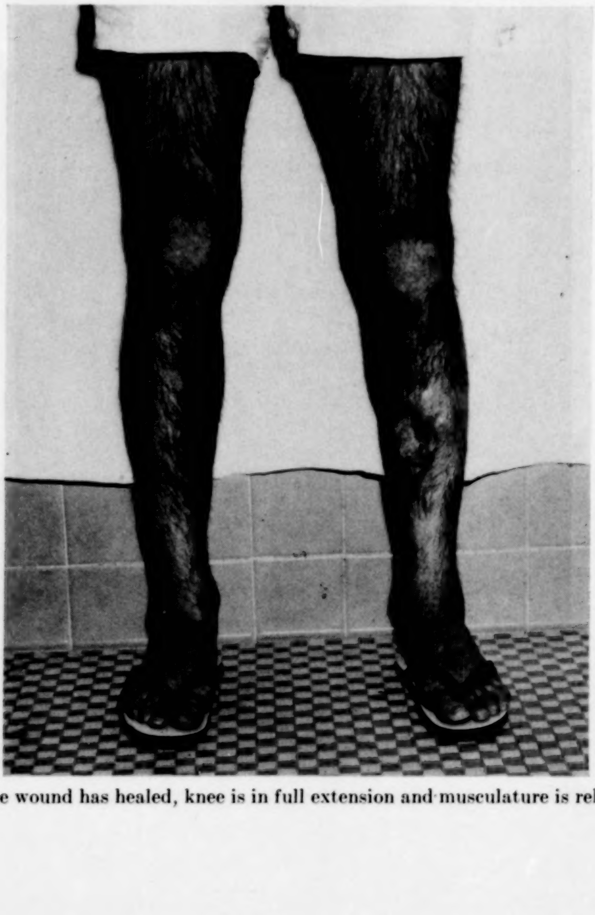

Fig. 5c. The wound has healed, knee is in full extension and musculature is rehabilitated

Mobilization After Release From Cast: We have no explanation for the fact that half of the patients showed limitation of motion of the knee joint with good ankle motion while the other half had a stiff ankle with good knee motion. In either case, following removal of the cast, the patient was placed for the first time during his treatment on absolute bed rest and was kept in bed for active mobilization until he had obtained full motion of all joints and normal muscular control. Only after this was achieved did he again become ambulatory (Figs. 5c & d).

RESULTS

The average time of healing and return to duty for all of our 207 patients was 5 months. In 88 per cent of the patients the time for healing and mobilization fell between 4 and 6 months. The remaining 12 per cent varied from 2 to 14 months being equally divided into slow and fast healing fractures. While we have released a small number of patients from immobilization 2 to 3 months after the injury, it has been our general policy to add another month of immobilization

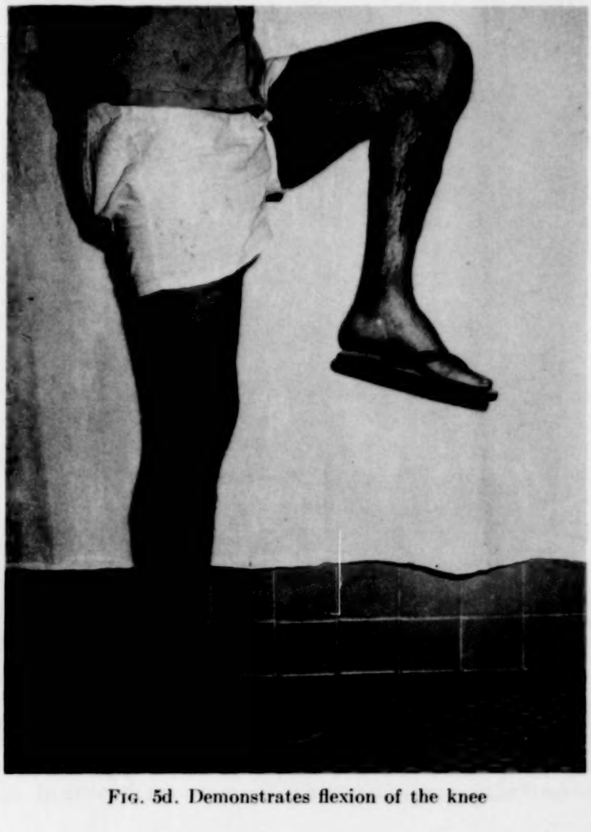

FIG. 5d. Demonstrates flexion of the knee

in the majority of cases, even after we felt that the union might be strong enough for weight bearing (Figs. 6a, b, c). The slower cases which required up to and beyond one year for healing were generally those with associated injuries or disease or severe compound injuries which had become infected.

While no uniform figures are available regarding overall healing time of fractured tibias, our results may well be plotted against the comparative study by Urist on 100 consecutive cases which he used as a control series in his fundamental study on the pathogenesis of delayed union and nonunion. In his series he had five undisplaced fractures which healed within 4 months. These are the only fractures with healing times comparable to our average. Otherwise, his healing times for closed plaster treatment for transverse, oblique and spiral fractures averaged 6 months, for butterfly fractures 12 to 18 months, and for segmental fractures 24 to 30 months. Amputation of the leg was necessary in three of seven comminuted fractures treated by open methods. In our series there were no amputations. Even the slowest case healed in 14 months. It may

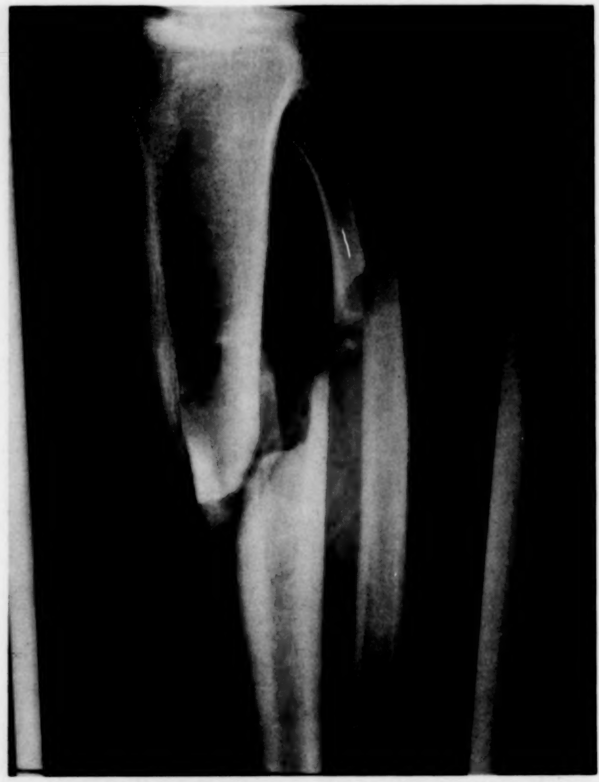

FIG. 6a. This fracture appears unstable. The patient started weight bearing the day after the fracture.

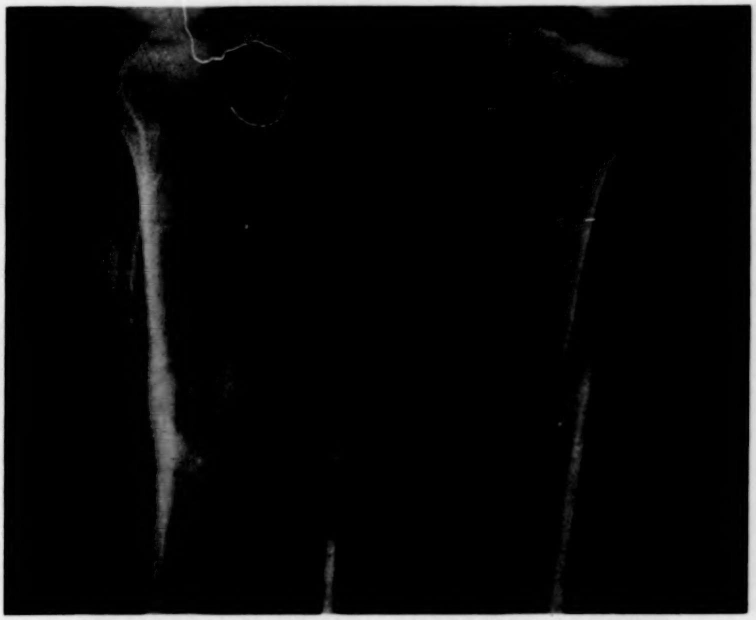

FIG. 6b. Six weeks later, portable x-rays show early consolidation by abundant preliminary callus without any additional loss of length.

also be noted that the type of fracture made considerable difference in the healing time in Urist's series; whereas, on the weight bearing management the type of fracture seemed to have no bearing on its healing time.

Compound Fractures: Eighty-eight per cent of our compound fractures were treated by debridement, 12 per cent by simple wound cleansing; 11 per cent of these wounds required skin grafts.

Infections: The total number of infections of the compound wounds is not known to us since infection in a number of cases was only manifested by drainage seen on the cast and the infection had spontaneously subsided prior to the first cast change, or at least by the time the fracture was healed. These benign forms of infection did not delay consolidation in comparison with the average of the total series. The most severe infections occurred in the compound fractures where primary closure had been attempted with or without releasing incisions, or with rotational flaps with subsequent breakdown of the skin. In these cases healing was delayed up to 14 months after the fracture. However, all went eventually to bony union and none of these cases required surgery for control of infection.

Our policy, whenever we received the patients for initial care, was to leave the wound open initially, employing secondary closure whenever indicated. Only one patient became infected after secondary closure and healed after 9 months.

Shortening: In general, no measurable shortening occurred beyond the position

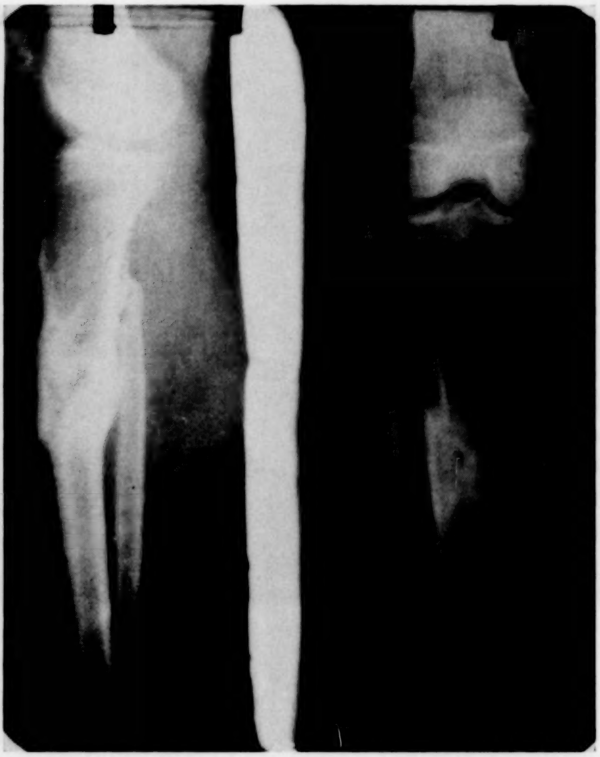

FIG. 6c. The patient returned to limited duty consisting of classroom work after 4 months, and to unrestricted military duty after 8 months.

initially accepted. Twenty-seven consecutive cases of the Fort Benning series were analyzed for eventual shortening as summarized in Table III.

Angulation: Angulation was again accurately measured in 27 consecutive cases of the Fort Benning series; 12 of these had some degree of varus or recurvatum, none exceeding 10 degrees. These minor degrees of deformity failed to impair the function or comfort of the patients. All cases recovered full range of motion of the knee and ankle, and all military personnel returned to duty (Figs. 7a & b).

Secondary Surgery: Five patients underwent secondary osteotomy of the fibula. The procedure was required in two cases of isolated fractures of the tibia without fracture of the fibula; and in three cases of delayed union, two of which had been caused by infection. Phemister type bone grafts were employed in three cases; one had a delayed union in a simple fracture and required a total of 14 months for consolidation. The second patient had been delayed in his ambulation by multiple co-existing fractures including a fracture of the femur treated in traction; and the third patient had sustained multiple fractures in a

TABLE III

Hospital	No. of Cases	Shortening of Leg Lengths
Martin Army Hospital Fort Benning, Ga.	10	0
	6	Less than ½ inch
	11	½ to ¾ inch

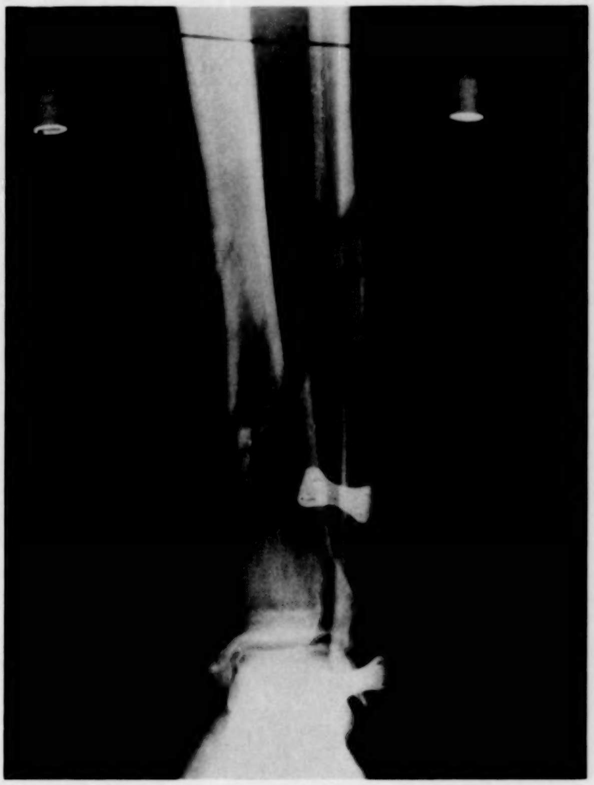

FIG. 7A. Compound fracture, segmental. The wound was cleaned and left open. The patient was ambulated the next day. Position of the fragments in the cast required realignment which was omitted on account of drainage noted on the cast. There was slight drainage on the first cast change, but when the patient returned to limited duty after 4 months the drainage had subsided.

helicopter crash with severe skin and bone destruction by repeated impact of the helicopter rotors against his shin.

Refractures: Refractures of the tibia were observed in three of our cases. The circumstances involved as well as the small number of cases of refracture does not permit any uniform conclusions in regard to our treatment.

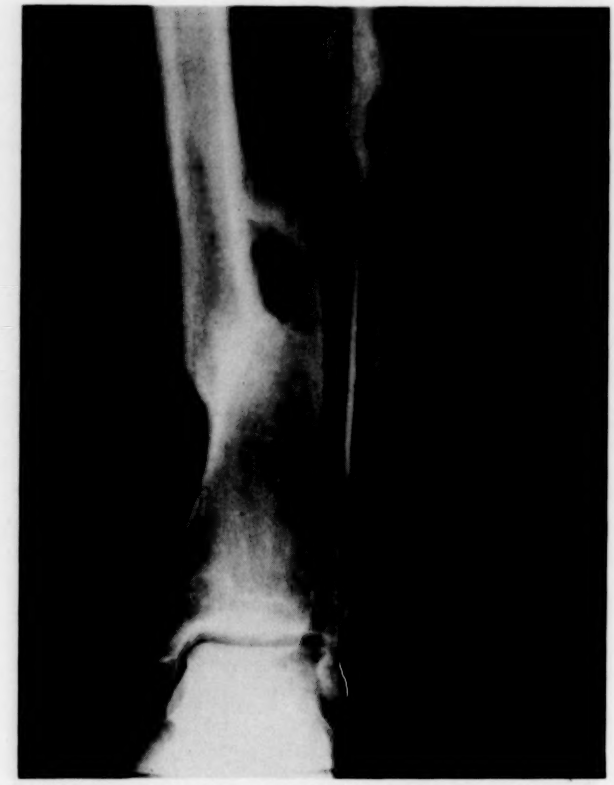

FIG. 7b. Follow-up x-rays 8 months after injury. By that time the patient had already accomplished two parachute jumps.

Case #1: The fracture had been considered healed after two months and the patient released from the cast at that time. Six weeks later he fell into a fox hole and fractured the same leg again.

Case #2: The patient fractured his leg which had previously been affected by osteomyelitis. The fracture was considered healed after 5 months. Two months later he broke his leg again. It was considered healed after an additional period of immobilization for 4 months.

Case #3: This patient suffered an undisplaced fracture of the right tibia and fibula in 1953 while playing football. He stated that he had an ankle injury at the same time which made him feel insecure on that leg. He sustained another undisplaced fracture of both bones of the same leg, at the same site, on 7 October 1960 (Fig. 8a). Three months later the fracture was considered healed and released from immobilization (Fig. 8b). Six weeks later he fell off a bleacher from a height of about five feet striking the side of his leg against the side of the bleacher and sustained a third fracture at the same site (Fig. 8c).

In the first case the patient may have been released too soon from immobiliza-

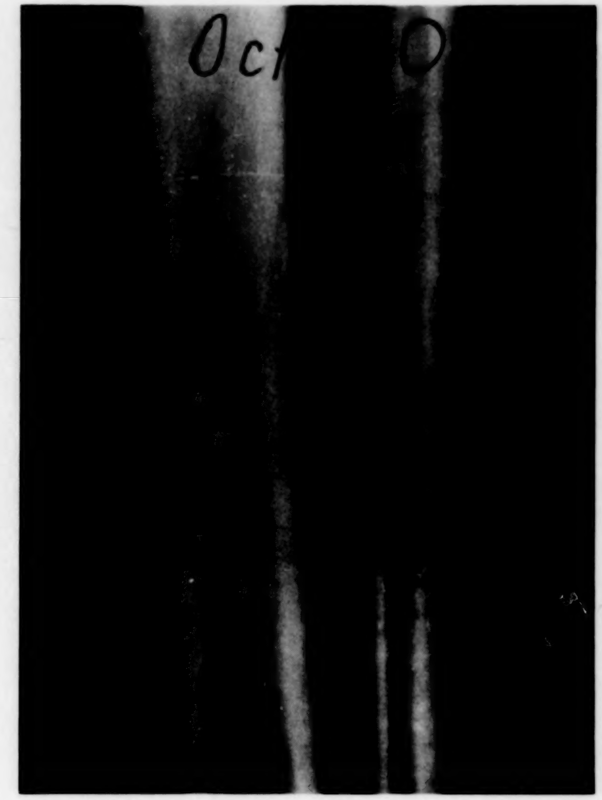

FIG. 8a. Undisplaced fracture of both bones of the right leg sustained in football. The identical site of fracture sustained 7 years earlier playing football.

tion, but the trauma was of sufficient severity so that he may conceivably have produced the fracture anyway. In both cases #2 and #3 union certainly appeared adequate to permit unsupported weight bearing.

Functional Recovery: Ninety-two per cent of the patients had full return of function, eight per cent healed with some impairment. The latter group was amongst the 17 per cent of patients who had associated injuries or disease.

The full functional recovery observed in the majority of our cases is contrasted by the high incidence of patients treated by other methods whose healing time exceeded one year. This dramatic contrast was obvious to all who had the opportunity to observe the difference in recovery rate between the ambulatory method and others when the new approach was introduced in each successive hospital.

SUMMARY

All 207 cases treated by immobilization in a near skin-tight cast with the knee held in full extension and with immediate weight bearing went to union.

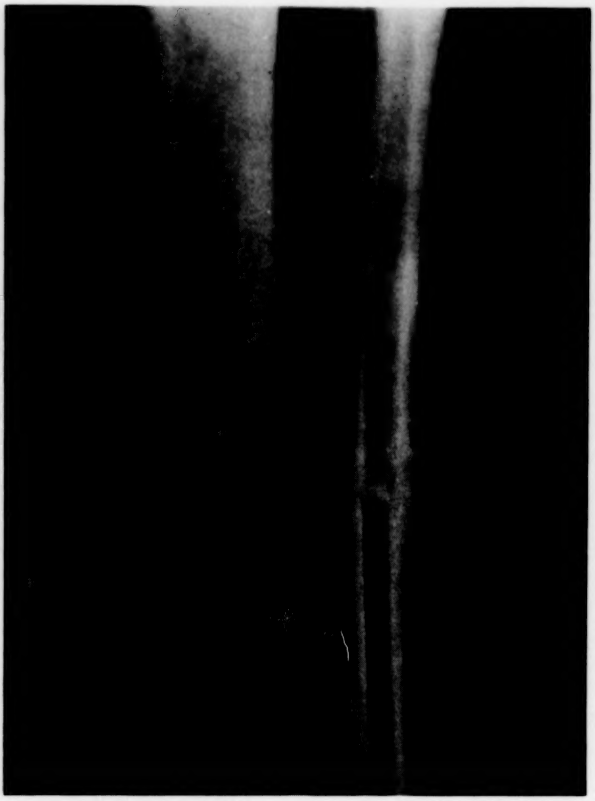

FIG. 8b. Three months later the fracture was solidly healed and the patient reassigned to limited military duty pending final evaluation.

The average time for healing and rehabilitation was 5 months. The fastest case was 7 weeks, the slowest was 14 months. Even our slowest cases do not approach the duration observed in cases delayed by surgery or traction. The consistency and rapidity of union obtained by our method becomes apparent by comparison with other series.

We believe that the consistency and rapidity of union obtained is attributable to the avoidance of surgery or traction with the acceptance of some minor degree of shortening.

The favorable functional results, we believe, may be attributed above all to the rapidity of healing of the bone, and also to the functional stimulation of continuous weight bearing and closer attention to rehabilitation.

REFERENCES

1. DEHNE, E. Die Osteosynthese der Unterschenkelbrueche. Arch. f. orthop. u. Unfall-Chir., **39:** 328–356, 1938.

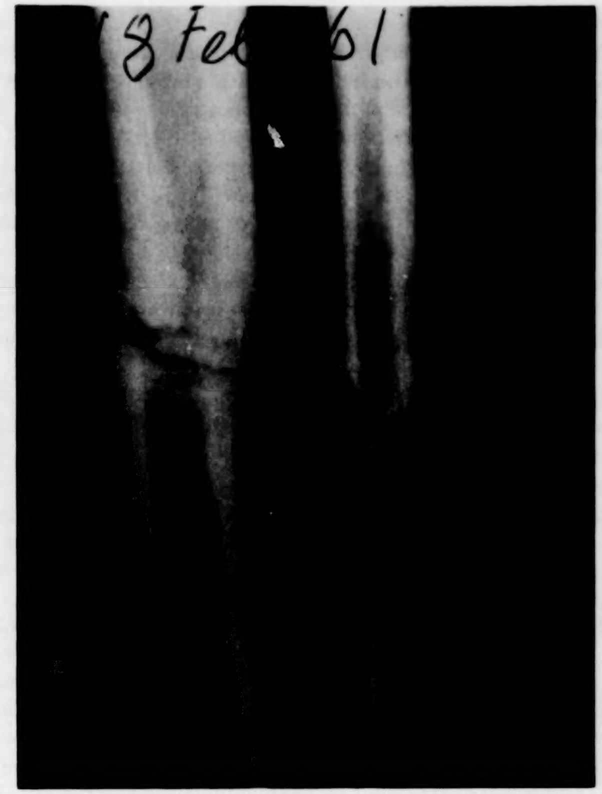

FIG. 8c. Four and one half months after the second fracture he fell off a bleacher and sustained his third undisplaced fracture at the same site.

2. COGGINS, F. W., Capt. MC. Fractures of the tibia and fibula. M. Bull., U. S. Army, Europe, **10:** 46–50, Feb. 1953.
3. URIST, M. R., MAZET, R., JR., AND MCLEAN, F. C. The pathogenesis and treatment of delayed union and non-union. J. Bone & Joint Surg., **36**-*A*: 931–968, Oct. 1954.

DISCUSSION

DR. OSCAR P. HAMPTON, JR. (St. Louis, Missouri): Dr. Stack, Members and Guests: Needless to say all of the papers have been enjoyable to all of us, and I am sure informative. I am in the position of having sponsored a paper on an all-inclusive non-operative method of management of these complex injuries, yet I am not in full agreement. It has been my privilege to see a number of the patients that were included in the series which Colonel Dehne presented, those under the name of Colonel Metz, at Walter Reed. Needless to say I was astounded at seeing comminuted fractures placed in a plaster cast walking with some weight bearing in a matter of days to, at the most, a few weeks. I didn't believe what I saw, yet it was there.

All the speakers have added evidence in favor of the concept that these fractures will heal and that to interfere with an open procedure is flirting with some danger. On the other hand, I can not accept that in everyone's hands the entire non-operative method for these injuries is applicable.

(Slide) This classification of stable and unstable fractures is familiar to all of you. What Colonel Dehne is doing, and the others have done to some extent in their presentations, is to call all these fractures stable. Well, in the hands of some of us, many fractures are unstable. The problem arises immediately, which method of management is the best for the patient?

Our objectives are all the same: a healed fracture without osteomyelitis, but also a functional restoration of the extremity. It is our job to apply the operative method when it is selected so as to avoid the catastrophes and achieve the objectives.

(Slide) In this particular fracture, a spiral oblique displaced fracture, Colonel Dehne would deny me the fun of operating on it. I submit, in that unusual fracture, that the total number of infections in competent hands with open reduction and internal fixation with a couple of screws should be no greater than the incidence of infection which would occur in a small percentage going on to non-union and requiring open operation and bone grafting. In other words, to me the conservative management of that fracture is what you see there, internal fixation with two screws.

(Slide) I can not help but come back to the method that Dr. Lottes in St. Louis has preached so much, and we thoroughly endorse: The early intramedullary nailing of fractures of the tibia. A closed reduction is preferable. The errors in intramedullary nailing of fractures of the tibia come from delayed application of the method, at a time when closed reduction can not be achieved.

(Slide) The only incision is at the proximal end of the tibia, and a closed reduction is performed at this point by the manipulating hand. A trickle of blood running down could not be avoided. But the only incision is here. It's a *closed reduction;* the method needs to be selected primarily.

(Slide) The only problem is getting it into the lower fragment, and the check x-ray confirms it. With a little experience it is not difficult when the patients are selected properly.

(Slide) Here is an application of the nail, the fracture that I am sure Colonel Dehne's groups would attempt to reduce and hold reduced in only a cast. In this instance a splendid result was achieved with a nail.

(Slide) Here is one that is a little more complex: a double fracture, segmental fracture. I am not so sure they can achieve closed reduction and hold it in a cast, but with the proper application of the nail, a splendid end result was achieved. It is a *closed* reduction, not an open reduction.

(Slide) I submit this patient, with an open fracture, an open wound down the shin, right along the crest of the tibia. To resort to closed methods here and allow the pressure of fragments against the skin from beneath risks necrosis of skin. With necrosis of skin comes infection, and incidentally, most of the infections with open reductions in fractures of the tibia result from ischemia of wound margins, from excessive swelling which occurs in the post-operative period. This hazard is obviated in the closed reduction and intramedullary nailing of fractures of the tibia. This is a rather comminuted fracture that I submit is unstable in anybody's classification.

(Slide) This is the result achieved with a primary intramedullary nailing, not delayed.

(Slide) And that is the end result.

So my thesis as part of this discussion is that there is a place for the closed reduction of fractures of the tibia which are complex, with primary intermedullary nailing, not delayed ten days, two weeks, later, when the fragments can no longer be reduced by manipulation.

THE RELATIONSHIP OF PHYSICAL HEALTH TO THE INCIDENCE OF ACCIDENTS

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INTRODUCTION

Accidental injuries continue to be one of the leading causes of death and morbidity in this country. In the last decade, research in both medicine and public health has been increasingly directed towards the many problems associated with the control of accidents. At present there is a growing awareness of the need for concerted effort to develop sound surgical and medical techniques for the treatment of accidents.

In the field of Public Health, an ever expanding fund of knowledge is being developed which bears on the epidemiology and etiology of accidental injuries. Consistent with its policy of encouraging accident research, the National Institutes of Health, in 1957, awarded a four-year research grant to the Connecticut State Department of Health for the purpose of investigating the frequencies and causes of accidental injuries in a typical Connecticut population. This research activity, known officially as the Family Injury Survey, collected information on 5,256 people representing a 17% systematic sample of the town of Norwich, Connecticut.

SOURCE OF DATA

The field work for the study was conducted from October, 1958 through September, 1959. Each month during this period a twelfth of the total sample population was interviewed. In addition to an initial interview, each household was visited four times at two-week intervals to gather information on all accidental injuries incurred during the period subsequent to the previous visit. During the first interview the following information was obtained: demographic data—age, sex, marital status, education, occupation, etc.; data on exposure to accident-conducive situations; data on the prevalence of disease and illness, including illness resulting from accidents; data on accidental injuries occurring in the previous two weeks; and data relating to the physical environment in which the family lived.

It should be noted here that accidents as recorded by the Family Injury Survey were defined as any chance or non-chance event which resulted in visible or internally felt bodily damage. Therefore, all accidents of either a serious or a minor nature which were reported were used in the following analyses.

The data which were collected have served many purposes. However, para-

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mount among the research objectives was the desire to learn what effect, if any, poor health has on the likelihood of an individual incurring an accident.

THE RELATIONSHIP BETWEEN ILLNESS AND ACCIDENTS

Since it appeared reasonable that people in ill health, and consequently debilitated to a certain extent, could not cope with their environment as well as people in good health, an attempt was made to determine whether or not persons afflicted with disease had a higher accident experience than those who are well.

Although it is difficult to hypothesize that a specific disease could increase the likelihood of an accident, many diseases both acute and chronic, could produce symptoms resulting in either long or short term debility. To the extent that a person's reactions, physical prowess, or judgment would be affected by such symptoms, a greater susceptibility to the intrinsic hazards of the physical environment might be anticipated.

At present, there is some controversy regarding the effect that physical health has on accidents. A report by McFarland cites several studies which have shown that drivers with impairments have safe driving records if they are carefully supervised by a physician (4).

Another study, comparing accident-repeater and accident-free pupils in the largest junior high school in the City of Yonkers, which assessed health through examination of medical histories, found no difference between the health of these two groups despite their difference in accident rates (1). It was also noted that accident-free pupils suffered more minor illnesses, while accident repeaters had more hearing, seeing, and orthopedic defects.

Two studies concerned specifically with the relationship between disease and accidents have reported results which are strikingly consistent, despite the fact that the sources of data used were quite different. The study by Collins, using interview data from the National Health Surveys of 1938 through 1943, showed that people fifteen years of age or older who had three or more accidents during a five-year period, were more often sufferers of chronic diseases than people who had no accidents (2).

The second study by Iskrant (3), using the hospital records of the inactive file of the Group Health Association, Washington, D. C., and analyzing all information on medically treated injuries and conditions of about 13,000 persons showed results similar to those of Collins. Iskrant states that the percentage treated for an injury was higher for those with at least one condition diagnosed, than in those persons for whom no condition was diagnosed. The difference in percentage is very pronounced when all ages and both sexes are considered as a total group, and the percentage is consistently higher up to age forty. It was also shown that there is a slight tendency for an increase in accidents to accompany an increase in conditions in most age groups.

THE MORBIDITY DATA

To collect data on morbid conditions in the Norwich population, the Family Injury Survey used the five questions concerning condition of health, as well as the instructions for interviewers, from the U. S. National Health Survey (5).

The information collected reports only those conditions known to, and reported by, the respondents and is, therefore, a minimum estimate of the presence of morbid conditions in the population. The only major departure from the National Health Survey procedure was that all conditions reported to the Family Injury Survey interviewers were tabulated regardless of whether or not they resulted in any disability. Conditions which had not received medical attention or diagnosis were also tabulated. All conditions reported by the respondents were then coded according to the *Intermediate List of 150 Causes for the Tabulation of Morbidity and Mortality* from the *International Classification of Diseases*, 1955 revision[1] (6).

NUMBER OF MORBID CONDITIONS AND ACCIDENT LIABILITY

Figures 1, 2, 3 and 4 demonstrate that those people having one condition, and those having more than one condition, had a higher proportion of accidents than those having no condition. For both sexes and all age groups, it will be noticed that only 22% of those having no condition had one or more accidents. On the other hand, 25% of those having one condition had one or more accidents, while 26% of those having more than one condition had accidents. This relationship holds rather consistently for both sexes and for the various age groups shown. Chi-square tests for contingency were performed, and in most cases differences were found to be significant at the 5% level or better.

Interestingly, these findings are consistent with those of Iskrant since both studies indicate that the liability to accidents increases directly with the number of conditions reported.

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[1] Certain modifications were made in the coding procedure since the information gathered was often not precise enough to code to specific categories. All forms of tuberculosis were coded 005, *Tuberculosis all other forms*. Unless a neoplasm was specifically named as cancer and defined as to location or type it was coded 060, *Benign neoplasms and neoplasms unspecified nature*. Almost all allergies were put in the Allergic disorders category (066) since often they could not be distinguished from Dermatitis. Only persons who were or had been institutionalized for Psychoses were coded 067. *Psychoneurosis and disorders of personality* (068) was the code used for all persons who complained of nervousness or tension. Although blindness and deafness were reported, most of these cases were put in code 078, *All other diseases of the nervous system and sense organs*, since they did not fit specific codes such as Glaucoma. Heart diseases which were not well defined were put in the category *Other diseases of the heart* (082). Influenza (088) was coded only if the person had symptoms lasting for some time, otherwise colds, viruses, and influenza were coded 087, *Acute upper respiratory infections*. All forms of pneumonia were called *Primary atypical, other and unspecified pneumonia* (091) due to a lack of more specific information. *Bronchitis, chronic and unqualified* 093, was the category used for all bronchitis since it was often impossible to distinguish between acute and chronic forms. Similarly, all sinus conditions were coded 097, *All other respiratory diseases*, and all ulcers were coded 099, *Ulcer of the stomach*. Vague digestive disorders were classified as *Other diseases of the digestive system* (107). Code 122, *Arthritis and spondylitis* was used for both arthritis and rheumatism since persons often could not distinguish between them. In the analysis, codes 138–149 were not used, code 137 being used for all ill-defined conditions.

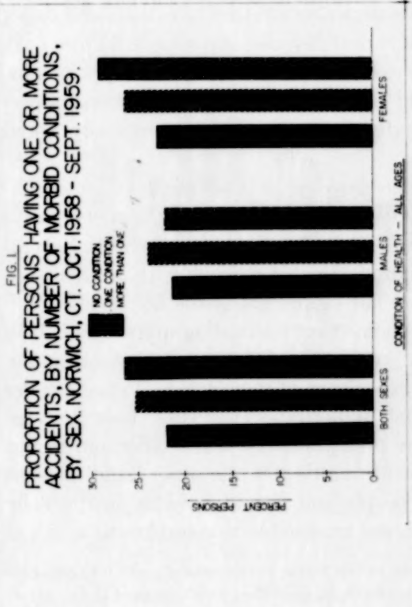

FIG. 1

PROPORTION OF PERSONS HAVING ONE OR MORE ACCIDENTS, BY NUMBER OF MORBID CONDITIONS, BY SEX. NORWICH, CT. OCT. 1958 - SEPT. 1959.

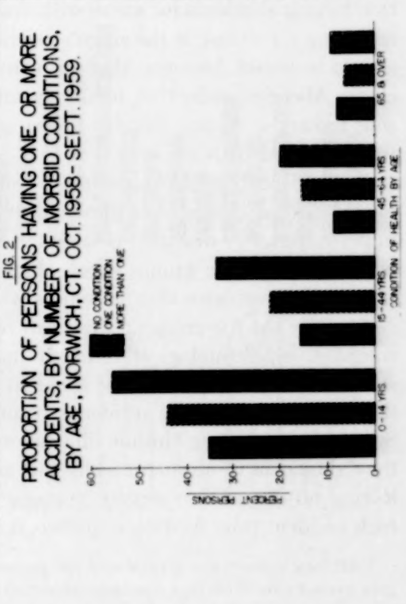

FIG. 2

PROPORTION OF PERSONS HAVING ONE OR MORE ACCIDENTS, BY NUMBER OF MORBID CONDITIONS, BY AGE, NORWICH, CT. OCT. 1958 - SEPT. 1959.

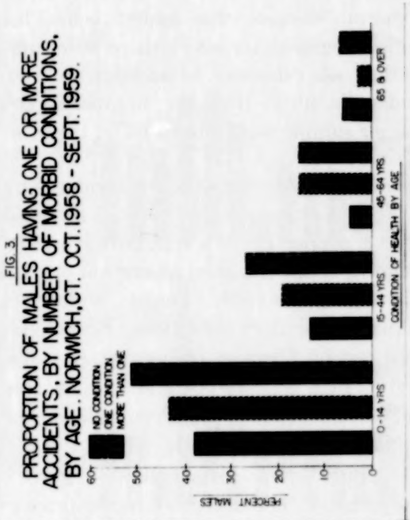

FIG. 3

PROPORTION OF MALES HAVING ONE OR MORE ACCIDENTS, BY NUMBER OF MORBID CONDITIONS, BY AGE. NORWICH, CT. OCT. 1958 - SEPT. 1959.

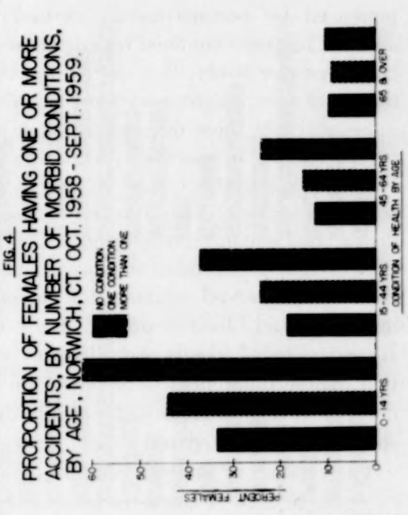

FIG. 4

PROPORTION OF FEMALES HAVING ONE OR MORE ACCIDENTS, BY NUMBER OF MORBID CONDITIONS, BY AGE, NORWICH, CT. OCT. 1958 - SEPT. 1959.

SPECIFIC DISEASE AND ACCIDENT LIABILITY[2]

In order to further explore the findings of the Family Injury Survey, as well as those of the several studies cited, an analysis of the number of accidents experienced by persons having certain specific diseases was undertaken. This analysis has been confined to only those disease groups for which there were sufficient cases for study. It is quite possible that other diseases, in addition to those discussed here, might contribute to accident liability. However, because of the infrequency of these diseases, a much larger sample would have to be taken to produce sufficient cases for proper analysis.

Figure 5 indicates the proportion of persons having one or more accidents by selected disease groups. Twenty-two per cent of those persons with no reported disease had one or more accidents. Using this proportion as a standard, it will be noticed that in several of the disease categories a much higher proportion of accidents was observed—namely for persons having Anemias; Allergies, endocrine, metabolic and blood disorders; Acute upper respiratory infections; Bronchitis; Hypertrophy of tonsils and adenoids, and certain Diseases of the digestive system. These differences were tested for statistical significance and in each case mentioned the probability of a chance difference as large as observed between the specific disease noted and those having no disease is 5% or less.

The method of analysis employed in Figures 6 and 7 is similar to Figure 5 except here each of the sexes is treated separately. The difference in the proportion having accidents for males with acute upper respiratory infections and males reporting no disease is the singular significant difference apparent in Figure 6. It should be noted, however, that with the exception of the disease group which includes Allergies, endocrine, metabolic and blood diseases, high proportions of persons having accidents occur in the same disease groups as was previously noted for persons of both sexes.

A significantly high proportion of females had one or more accidents in the following disease groups: Allergies, endocrine, metabolic and blood disorders; Acute upper respiratory diseases; Bronchitis; and all other respiratory diseases. Several of the other disease groups show a high proportion of persons with accidents although in these cases the differences were not significant at the 5% level.

Actually the foregoing analysis can be somewhat misleading unless age is held constant. Epidemiological research has consistently indicated that there are striking age differentials in the accident experience of populations. Persons under the age of 15 experience accidents at much higher rates than those over this age. Since persons having chronic illnesses are predominately in the older age groups they should have an intrinsically low accident rate. On the other hand, persons having no disease are usually younger people and should have an intrinsically high accident rate. As a consequence, it is not reasonable to compare the accident

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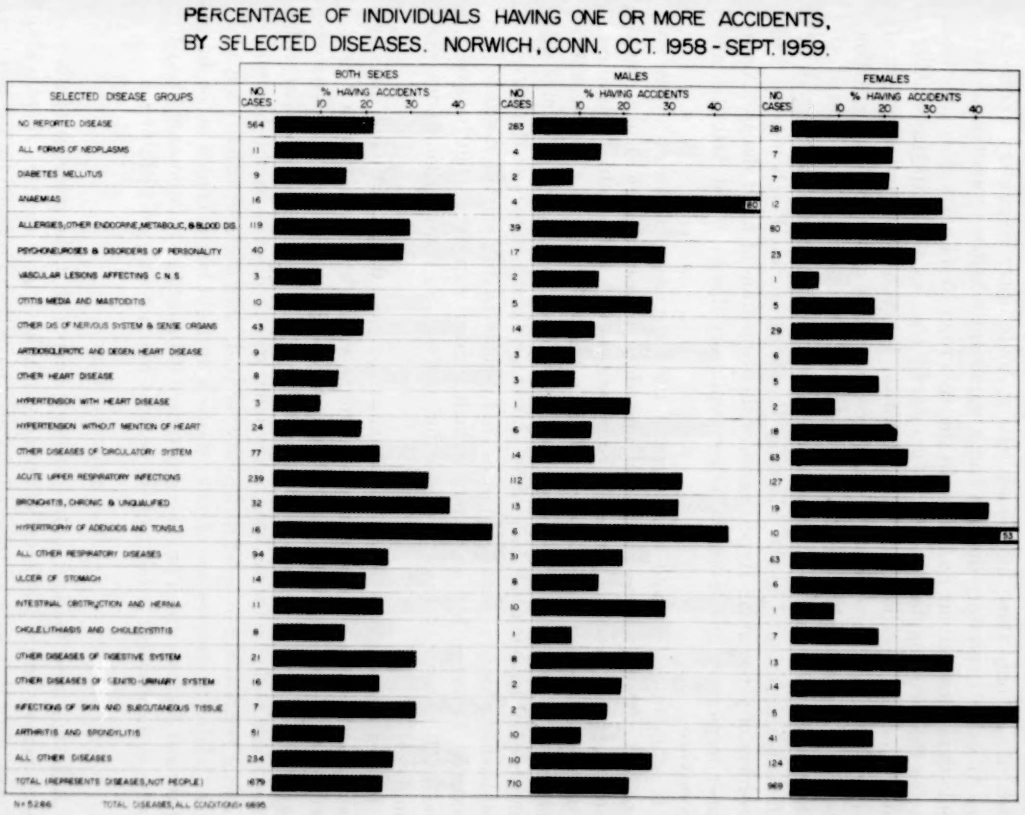
[2] Although there was a total of 5,256 persons in the Survey, the totals seen in the figures may exceed this since many persons reported more than one illness and entered the analysis more than once. This, however, does not bias the results since persons in each specific disease category were independently compared to persons having no disease but no comparisons were made between categories.



PERCENTAGE OF INDIVIDUALS HAVING ONE OR MORE ACCIDENTS, BY SELECTED DISEASES. NORWICH, CONN. OCT. 1958 - SEPT. 1959.

FIGURES 5, 6, 7

experience of individuals with chronic illness with those having no disease unless the analysis is confined to homogeneous age groups.

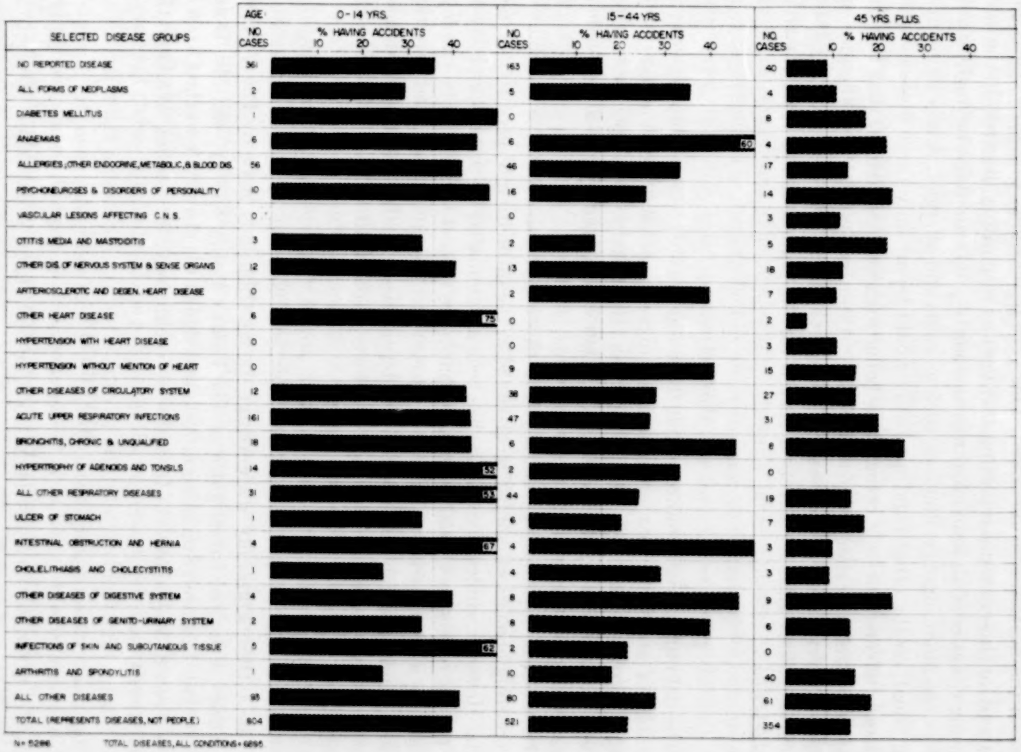
Figures 8, 9, and 10 indicate the proportions of persons having one or more accidents in each of the selected disease groups by age. In the case of persons 0–14 years of age, only those individuals having Acute upper respiratory infections and All other respiratory diseases had a significantly higher proportion of accidents than those having no illness. In the age group 15–44 years of age, persons having the following diseases had a significantly high accident experience: Allergies, endocrine, metabolic and blood diseases; Psychoneurosis and disorders of personality; All other diseases of the nervous system and sense organs; Other diseases of the respiratory system; Acute upper respiratory infections; and All other respiratory diseases. For persons 45 years of age and older, significant differences were found in the following disease categories: Psychoneurosis and disorders of personality; Hypertension without mention of heart disease; Acute upper respiratory infections; All other respiratory diseases; and Arthritis, and spondylitis.

It is important to note that in all of the foregoing analyses an extremely stringent criterion was used in determining which disease categories had a significantly high proportion of persons having one or more accidents. In all instances, a difference was only considered significant if the probability of a chance difference was 5 in 100 or less. In several cases, differences approached this level of significance but have not been singled out since they did not quite meet the criterion established. Also, in many instances, individuals having certain diseases (for example, Diabetes) had an extremely high accident experience, but because of the small number of cases available for analysis, no test of significance was employed.

Figures 5 through 10 reveal that in most instances the proportion of persons having accidents in the selected disease groups was higher than the proportion of persons having accidents among those who had no illness. Findings of this nature have two implications: First, there is probably good reason to believe that with more cases available for analysis, many more specific diseases would show a significant relationship to accident liability; second, since accident liability appears to be related to the presence of many diseases, it might be reasonable to conclude that most diseases which produce generalized debilitating symptoms are likely to increase the accident liability of the persons who are afflicted with them.

REPORTING BIAS

Although these findings adduce strong evidence that the presence of disease bears heavily on the likelihood of an individual having an accident, there is also a possibility that some of these effects may have been produced by the manner in which the data were collected. It is quite possible that within any population being interviewed there are two groups of individuals: those who have a tendency to report things fully and accurately, and those who do not report accurately. Therefore, it is possible that some individuals who were very eager to report the presence of morbid conditions were equally willing to report to the interviewer



PERCENTAGE OF INDIVIDUALS HAVING ONE OR MORE ACCIDENTS,
BY AGE AND SELECTED DISEASES. NORWICH, CONN. OCT. 1958 - SEPT. 1959.

N = 5286 TOTAL DISEASES, ALL CONDITIONS = 6895

FIGURES 8, 9, 10

every accident which they could remember. On the other hand, there might also have been many individuals who did not choose to report either their illnesses or their accidents. If such a bias as this exists in the data, it might very well reflect itself in the relationships discussed. This type of bias might be particularly pronounced for those persons reporting allergies and respiratory diseases. In the interviewing situation if an individual was anxious to cooperate fully, he might readily report the more common illnesses, such as colds and allergies. A less cooperative individual, on the other hand, probably would report only those diseases which seriously affected his well being. It is being suggested, therefore, that the very pronounced effects that were reported for those persons having allergies and colds may very well be the result of a reporting bias. On the other hand, it is much less likely that the effects observed for the chronic illnesses are the result of such bias.

SUMMARY

The data offered here indicate that there is a positive relationship between the number of accidents that an individual experiences and the condition of his health. Further, there is evidence that this relationship is not specific to a particular disease or group of diseases, but rather is produced by any illness which is capable of producing debilitating symptoms.

Because the methodology employed in this research permits the possibility of a reporting bias, caution must be observed in the ultimate interpretation of these data. However, sufficient evidence has been accumulated by this research, as well as that of others to virtually demand that more refined techniques be employed in an attempt to arrive at definitive answers to the questions raised here. It is evident that research into the relationship between health and the incidence of accidents may be one of the most productive and fruitful areas of accident research.

ACKNOWLEDGMENTS

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REFERENCES

1. Birnbach, Sidney B., Ed.D. *A Comparative Study of Accident-Repeater and Accident-Free Pupils.* Center for Safety Education, Division of General Education, New York University.
2. Collins, S. D., Phillips, F. R. and Oliver, D. S. Accident frequency by specific cause and by nature and site of injury; sample of white families canvassed at monthly intervals, Eastern Health District of Baltimore, 1938–43. *Public Health Monogr.*, **14:** 1–22, 1953.
3. Iskrant, Albert P. *Accidental Injuries and Medical Conditions.* (A Study from the Records of the Inactive File of the Group Health Association, Washington, D. C., July, 1959) Unpublished.

4. McFarland, R. A. Health and Safety in Transportation, *Pub. Health Rep.*, **73:** 663–680, 1958.
5. U. S. National Health Survey, *Concepts and Definitions in the Health Household-Interview Survey*. U. S. Department of Health, Education and Welfare, Public Health Service, Division of Public Health Methods, 1958.
6. World Health Organization, *Manual of the International Statistical Classification of Diseases, Injuries and Causes of Death*, 1955 Revision, Vols. 1 and 2, Geneva, 1957.

DISCUSSION

Dr. Paul W. Braunstein (New York, New York): Dr. Waxman has presented an excellent statistical correlation of the relationship between acute and chronic disease to accident experience. As he has mentioned, this is an extremely difficult type of research. There are many conditions that are necessary to reach any valid conclusions. The first is the extremely large numbers of cases which must be examined and controlled in order to come to some definite conclusions.

Secondly, the study must be free of examiner bias. This is very difficult, because any researcher is always hoping, if only subconsciously, to prove a point which he starts out to make.

This work must be free of subject bias, such as the little old lady who likes to be examined and will tell the examiner almost anything as long as it will please him.

It is difficult to set up good controls for this type of work. It again requires large numbers of cases which are used only as controls and have nothing to do with the point to be proven.

Careful statistical analysis must be carried out, and this must be done by sophisticated researchers where interpretation can be done through discussion and with careful realization of the many possible pitfalls, as any variable in this type of work can seriously alter the conclusions.

It is extremely difficult for me, as a clinical researcher, without the help of statistical consultants, to carry on any type of work with large numbers. But I do think that this type of equational material impresses upon one the innumerable variables in any type of work such as this, and it is very important that one realizes that there may be many coincidental conclusions, rather than cause and effect, when one studies such demographic data, as have been presented today.

I think this type of work is quite important. It is only by collecting large amounts of these data and collating them on the national level that one can hope to pick out what areas are fruitful for further study in accident prevention, and then to implement these findings into safety action programs on national or local levels.

I think I should stress again that it is extremely difficult to relate environmental data to accident causation, and it is more difficult, in taking these data, to influence the observed pathological conditions and the accident experience that one hopes to alter or change.

About three years ago many people interested in this field, both clinicians and statisticians, met at N.Y.U. in an attempt to set up certain physical parameters to driver licensing. It became almost ridiculous to see one try to figure out how much the cervical spine should rotate to afford enough lateral vision for a driver. Conclusions were extremely difficult to arrive at, especially when one had absolutely no idea how many of these physical disabilities actually were causative as well as coincidental with accidents.

In Cornell in the pedestrian field and in the automotive field we have found certain diseases which we think very definitely affect accident experience. We found that the aged pedestrian is very prone to accident. We found that the lawbreaker, the one who won't cross at the corner, and so on, was very prone to accident, and we found that the young, wild driver was quite a problem.

And lastly, and probably a very, very fruitful area, is the alcoholic. In our pedestrian deaths in our Cornell study we found that 50 per cent of the adult fatalities had some significant level of blood alcohol and brain alcohol at autopsy.

I think that this is an extremely complicated type of work that Dr. Waxman is doing, and it is only through this type of work, with national effort, that we can possibly enter into this area of accident prevention.

Dr. Bruce D. Waxman (Hartford, Connecticut) (Closing):

I am terribly excited about these data that I put before you this afternoon. I think the implications of this sort of thing are enormous. Many of us in the public health field have felt for a long time that it would be a very good thing if Motor Vehicle Departments began to insist that physical examinations be given to automobile drivers. I know that politically as well as medically this is a very complex issue, except I do feel that we now have sufficient evidence to lead us to the conclusion that such examinations may be very important.

A man who is ill, especially with certain of the chronic diseases, probably should not drive an automobile or, if he is going to drive an automobile, ought to be driving under fairly restricted conditions. I think if we expect to reduce automobile accidents we are going to have to take a very hard-headed approach to this problem, and I think a hard-headed approach to the problem may be supported by such data as I have put before you this afternoon. I think it is something that is eminently worth our consideration.

TRAUMA NEWS

Edited by
JAMES K. STACK, M.D.

A press release was issued by the American College of Surgeons in June of this year reiterating its stand on total agreement with the American Medical Association and the National Safety Council and United States Public Health Service in urging the installation of seat belts as an essential measure in saving lives and lessening the extent of injuries. Dr. Paul North, the Director of the College, pointed out that at the Annual Clinical Congress in 1954 the first presentation at any national medical meeting featured a symposium on "Prevention of Front-Seat Automobile Injuries." In 1955, the Board of Regents of the College formally urged automobile manufacturers to install this safety device. The Joint Action Program, participated in by the American College of Surgeons, the National Safety Council and the American Association for the Surgery of Trauma, has also pressed for the seat belt to be standard automobile equipment. That this campaign is bearing fruit is evidenced by the fact that in 1962 all five major automobile manufacturers will have in their cars the basic equipment to which seat belts may be attached. This basic equipment will be standard and not optional. The University of Nebraska's Campus Safety Committee recommended to the administration that seat belts be installed in all University cars. This was approved. The Campus Safety Committee emphasized that it is just as important to use the seat belt on short trips in town as well as longer trips on the highway. It has been shown that three out of four traffic deaths occur within 25 miles of home. It has also been shown that in the year 1960 8,000 to 10,000 lives would have been saved had these victims worn seat belts. The chances of being killed in an accident are five times greater if one is thrown from the car. Many people still have the notion that protection is not needed at lower speeds. More than half of the accidents causing injury or death involve speeds of less than 40 miles per hour, and certainly the seat belt will prevent, or lessen, injury under these circumstances. Many people erroneously think that the seat belt is a hazard in case of fire or submersion. Contrary to this belief, seat belts greatly improve the chances of surviving an accident that involves fire or submersion. The seat belt can be unfastened in an instant with one hand, and it will increase one's chances of remaining conscious so that he can get clear of the submerged or burning car.

Recently, the National Safety Council has featured the Roy Campanella story. You will recall that in January of 1958 the star catcher of the Dodgers was driving a car that skidded on a wet pavement at a speed of only 30 miles an hour. Campie wore no seat belt, and he was wedged under the dashboard after being thrown from the seat. As you know, he is permanently paralyzed at this time, and what is generally not known is that the vehicle, itself, sustained only minor damage. One year after this accident Campie, in his paralyzed condition, was again in an automobile accident, but this time he, of necessity, was wearing a seat belt. This second accident occurred at 40 miles an hour, and he was uninjured. Three others in the car with him who were not wearing seat belts were all hospitalized. The Safety Council cites the story of another victim, this time a woman driving a Volkswagon involved in a relatively minor collision. However, she was not using the seat belts that were present, was thrown from the car and another car ran over her and killed her.

In emphasizing the desirability of the seat belt to our patients, some fundamental facts should be told. When a car crashes, the motorist without a seat belt to stop him flies forward at unreduced speed, for a split-second still uninjured until he hits something solid. This is the impact that kills and maims. It is the violence of the reduction in speed, not the speed, itself, which kills. Thus, even lowspeed collisions can produce high deceleration rates. Seat belts help prevent injury by letting the body slow down and live. In many ways, the human body is remarkably durable. It can survive far greater jolts than are experienced in most automobile crashes, provided the body does not strike, or is not struck, by some hard or sharp object in the interior of the automobile. It should be remembered that Colonel Stapp has subjected himself to crash stops from 632 miles per hour to 0 miles per hour in 1.4 seconds. He suffered no disability because he was held in his seat by belts. These made it possible for him to come to a comparatively gradual stop.

In the studies of Cornell University's Automotive Crash Injury Research Program, it was shown that the seat belt will help the occupant stay inside the car where he is much safer. 12.8 per cent of car occupants ejected through open doors were killed, but only 2.6 per cent of those who remained in the cars were killed. Everyone is safer when the driver is kept behind the wheel. In case of an unexpected crash or sudden swerve, a seat belt keeps the driver from being thrown from behind the wheel; thus, he stays in control of the car and can prevent an additional crash. Each passenger should have a belt, in the back seat as well as the front, and it is especially important for youngsters, since they can be thrown forward so easily by sudden stops.

The seat belt chosen should be one that measures up to the standards of the Society of Automotive Engineers. These standards are concerned with breaking strength, ease of release and resistance to corrosion.

That the automotive seat belt is the most effective single item of protective equipment presently available to reduce the toll of traffic injuries and death is brought out by the dramatic story of Donald Campbell, a British speed ace. His Bluebird II flipped over and crashed at more than 300 miles an hour on the salt flats of Utah. Because he was wearing a seat belt, he walked into a hospital to receive first-aid for his minor injuries.

There is a difference between the quick and the dead, and that difference very often is the seat belt.

It is hoped that the installation of other protective equipment inside the car will soon be standard also. These would include crash padding of the dashboard, roof and other impact areas, improving the steering wheel with recessed post, perhaps a collapsible assembly, putting safety door locks on all motor vehicles, eliminating protruding knobs, buttons, handles and sharp edges, improving anchorage of the seats in motor vehicles. The seats should be high enough to protect the neck and to prevent the hyper-extension injury of the cervical spine that occurs in rear-end collisions. Improved storage space behind the rear seat would protect passengers from the possibility of injury by flying objects.

EDITORIAL

RESPONSIBILITY TO THE INJURED

Responsibility to the injured is a tremendous challenge to the medical profession. Trauma is the greatest cause of death in children from one to fourteen years of age. About two hundred and seventy people are killed daily from all causes. Traffic accidents kill one hundred people and injure about three hundred and fifty daily—four and fourteen respectively every hour. The yearly economic loss from accidents is about ten billion dollars—twenty-six million five hundred thousand daily. The first amount was three times the national debt of the United States shortly after the Civil War. The medical costs for injuries is about seven hundred million dollars yearly; two million daily; eighty-four thousand hourly; fourteen hundred every minute; twenty-three every second. The modern automobile improperly driven has become the most dangerous weapon ever placed in the hands of a civilian population. The Korean War killed an average of eight thousand five hundred thirty-four boys a year. Four times as many were killed in one year on our highways.

The success of definitive management and the ultimate rehabilitation of a severely injured person are dependent upon the initial handling of the emergency. Proper immediate care often decides the outcome, and is an important part of subsequent definitive management of the injury. It is hard to separate one from the other. It is a continuous process. Transportation thus becomes a major problem. In the majority of cases, immediate care and transportation are handled by ambulance attendants and in many localities, morticians control the private ambulance service. It would seem logical that each ambulance attendant should qualify for this important responsibility. It is recommended that an educational program be projected in every community and ambulance attendants be certified as to their efficiency. This program can be broadened further to include police, firemen, and anyone charged with the responsibility of the immediate care and transportation of injured persons.

The ambulance does not need to speed. The patient deserves a safe ride to the hospital.

The emergency receiving department of any hospital should be advantageously located for receiving patients. Active and supportive treatment should be readily available and organization should be projected to expedite quick action. Efficient nursing supervision is mandatory and should be continuous for twenty-four hours. X-ray facilities should be immediately available at all times. A blood bank is essential.

In hospitals with house staffs, it is strongly advised that an intern be assigned to emergency department duty on a full-time basis for selected periods during his training. If there are residents, the intern should be advised to call on them for help whenever necessary as a part of his general training. In hospitals without house staffs, selected members of the attending staff may be used.

Certain prerogatives and limitations must be projected by an organized educational program in any hospital having a house staff, irrespective of the size of the staff or institution. It is important that when a house officer asks for help it is immediately available. Delays and indecision in the problems of trauma surgery are dangerous. In hospitals having active attending staff organization, members should be assigned to active duty at regular intervals and should be available at all times. It is axiomatic that the patient should be considered as a whole. The person with multiple injuries represents an acute, complex problem and takes priority.

In hospital management, the patient's injuries should be individualized. Over-all appraisal is mandatory, with consultation requested freely when necessary. Pride should not enter into such important deliberations. Serious osseous injuries may be managed definitively, coincidental with associated injuries, provided the latter are recognized and under control and the patient has been stabilized. Delay at this point may produce a deconditioning process and the golden opportunity passes.

Events in the history of a traumatized person should have close continuity from the time of injury to the time of discharge. These should include immediate roadside care, efficient transportation, careful emergency room management and proper and timely selection of definitive care. Operative and post-operative facilities in the hospital should be adequate and handy. Outdated equipment should be discarded. Frequent check-up of the armamentarium for the surgery of trauma is recommended. In hospitals where a great deal of this work is done, organization under the direction of a qualified surgeon is a must for the maintenance of high standards.

Post-operative care must be of high quality to achieve desired results. Intense interest in this regard on the part of the surgeon in charge keeps the chain unbroken through the house staff, nursing personnel, ward helpers and orderlies. Nutrition and food balance are obvious. Good bedside care is most important.

Regular conferences are an important part of the organization of any surgical section. All cases are seen. "One should be critical of success and honest with mistakes."

Follow-up care, short-term and long-term, concludes the story. It is not important where and how this is done as long as it is done. In larger hospitals with training programs for interns and residents, a regular follow-up clinic is advisable. Results are evaluated and the patient is seen by the house and attending staffs. Further end-result studies, in groups, complete the chain of events.

Hospitals without house staffs will have to organize the attending medical staff to carry out these principles. The surgeon in charge must see that his patient has all the advantages of good management according to sound principles and policies.

Educational activities arranged for the profession are strongly recommended. Parts of any county society scientific program and any hospital staff meeting should be devoted to the surgery of trauma. Special symposia should be given at selected times during the year in various sections of any state. These can be arranged by local Regional Committees on Trauma, American College of Surgeons or by a State Committee Member in those districts where committees do not exist. Diversification of subjects is recommended. The teaching of trauma in medical schools should be revamped and clinical application of principles made available to undergraduate students.

Responsibility to the injured begins with:

A. Prevention

1. A well organized traffic safety program.
2. Driver education.
3. Improvement in highway construction.
4. More stringent requirements for driver licensure.
5. Safety in automobile design.

B. Education and certification of the ambulance attendant to insure better immediate care and transportation to the hospital.

C. Well equipped and organized emergency receiving departments of hospitals; around the clock care by house staffs, interns and residents under staff section supervision and instruction; experienced nursing supervision and adequate help, and adequate facilities for thorough evaluation of the injured person (x-ray, splinting of fractures, etc.).

D. Transportation within the hospital—efficient, speedy, and elimination of unnecessary handling.

E. Good staff organization consisting of qualified and experienced surgeons to render proper and expeditious care, assisted by specialty consultants; continuous appraisal of work done, by regular section conferences and rounds, clinical investigation assignments and critical analysis. A competent "team captain" is strongly recommended.

F. Long term follow-up care at regular intervals.

G. Rehabilitation

Responsibility to the injured ends only when maximum restoration has been obtained anatomically, functionally and economically.

George J. Curry, M.D

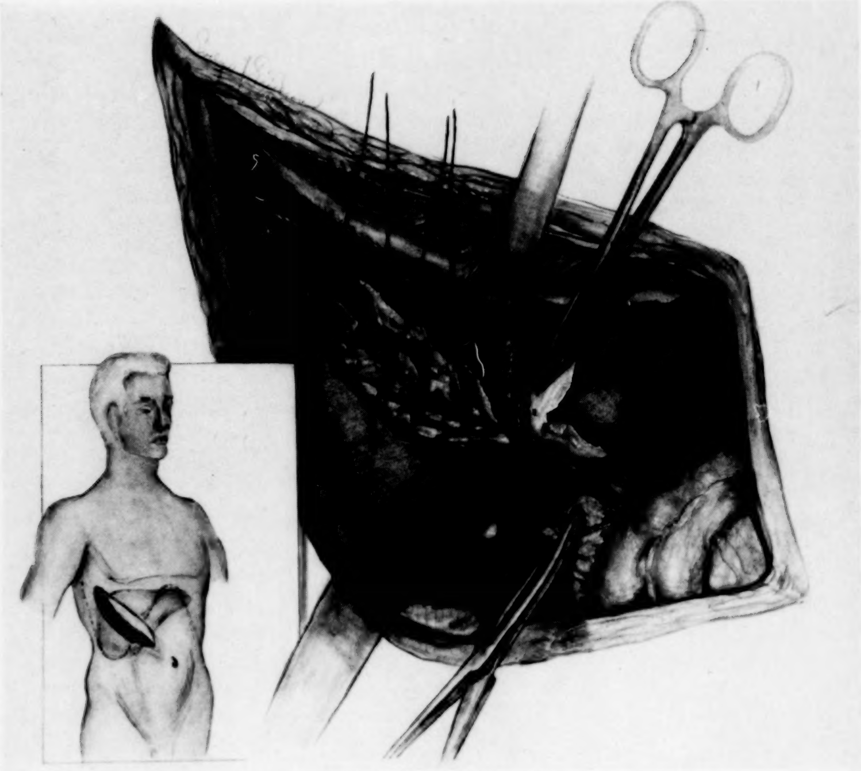

FIG. 1. Bursting injury of liver

BURSTING INJURIES OF THE LIVER

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Severe blunt trauma to the abdomen or chest may be associated with injury to the liver. Hemorrhage causes an immediate threat to life, and the complications which ensue may be numerous.

This report is of 20 cases of non-penetrating injuries of the liver treated between 1954 and 1959, at the Detroit Receiving Hospital. This does not include penetrating injuries which are rather common and could increase the group to approximately 200 cases. Particular reference is made to the advantages of portal triad compression for controlling rapid exsanguination due to central rupture of the liver, the dangers inherent in the use of the gauze pack for prolonged periods, and the use of the thoraco-abdominal extension of the incision when justified for adequate exposure to control rapid exsanguination.

There is no standard method of treating ruptures of the liver as they vary much in extent. It is understood that blood replacement, early operation and antibiotic therapy are important in the treatment.

Cause of rupture in each case was that of direct trauma over the area of the liver. A frequent history of injury in this series was that a pedestrian had been hit by an automobile. The hood over the headlight may commonly hit at the level of the liver (Table 1). A second most common cause was injury from the steering wheel during an automobile accident.

The diagnosis may not be suspected from casual observation of the patient since in many there may not be any observable soft tissue injury over the abdomen or the chest. Severe associated injuries are common. The patient may be stuporous, confused, cyanotic or entirely unconscious. Even in these a high accuracy of diagnosis may be obtained. The most common finding was shock unexplained by external bleeding. Abdominal pain without shock may be present.

Abdominal taps have been of diagnostic help. They were done on 17 of the 20 cases and found to be of diagnostic help in 80 per cent of the cases which were tapped. The most frequent area of productive taps was the right upper quadrant. Blood, both fresh and old, was aspirated.

Of the 20 cases, only 2 had a preoperative diagnosis of ruptured spleen, and in these the left side of the abdomen was initially entered. Associated injuries such as fractures of ribs and extremities were common, each occurring in 28 per cent of the cases. Ribs were commonly fractured on the right. Pelvic fractures represented 24 per cent of the associated series. Except for minor injuries to the

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[1] Present address: Honolulu, Hawaii.

[2] Present address: Florence, Italy.

TABLE 1

Cause for Rupture of Liver

Pedestrian	8
Auto accident	8
Fall	2
Blow to chest	2

TABLE 2

Operative Management

	Lived	Died
Suture repair	10	3
Suture and packing	2	3
Packing only	1	1

mesentery and omentum, there were no significant injuries to a hollow viscus. Hemobilia was not observed; however its presence would lead one to suspect a central rupture of the liver.

Operative management was of two principal types (Table 2). The most frequent method used was that in which various suture techniques were employed for reestablishment of liver contour and for hemostasis. Thirteen cases were handled in this fashion with 3 deaths. In a second group, gauze packing was used in conjunction with incomplete control from suturing of the liver. Complications were much more frequent in this group. There were 2 cases in which gauze packs alone were placed for hemostatic purposes in addition to soft rubber drains.

We have listed as complications any abnormal findings at any time during the postoperative period. A total of 23 major complications were present. The most serious and also the most prevalent was that of continued bleeding. This led to other complications such as pelvic abscess, subphrenic abscess and intestinal obstruction. The 2 external biliary fistulae occurred in patients in whom prolonged gauze packs were placed. When these were removed at subsequent operation, there were large amounts of both clotted and liquefied blood that drained. Subsequently one patient had to be drained posteriorly by removing a segment of the 10th rib and placing a drain between the pleura and vertebrae, creating true posterior dependent drainage. It appears that active bleeding had continued with a resultant collection in the immediate pack site.

It seemed that once packing had been used recurrent hemorrhage followed and frequent repacking became necessary along with a prolonged complicated hospital course. Hemostatic gauze or absorbable forms of cellulose were not often used, as profuse bleeding has the effect of floating them off the bleeding area without producing significant hemostasis. They were unsatisfactory in all instances where the need was great.

There were 9 cases in which a combined thoraco-abdominal incision was utilized. This represented an extension from an initial abdominal incision. In the remainder of the patients, abdominal incisions were adequate. The combined thoraco-abdominal incision gave good exposure in those severe bursting injuries in which the bare area or posterior aspect of the liver was extensively and deeply damaged. Where a repeat operation was necessary because of recurrent shock, the thoraco-abdominal incision gave excellent exposure necessary to obtain complete hemostasis and reconstitute the liver (Fig. 1) (Frontispiece).

Where bleeding is excessive and blood pressures are unobtainable, special measures may be required. The vascular bundle in the hepatoduodenal ligament was occluded in 5 instances to control rapid exsanguination from central rupture of the liver. This saves blood, maintains blood pressure, and makes it possible to individually ligate the hepatic vessels where there has been a large stellate rupture of the liver. Swaged No. 0000 and 00000 cardiovascular sutures were very helpful. Intermittent occlusion was most commonly used. Up to 30 minutes occlusion time was utilized in some instances. There were no unusual sequelae, and liver studies during convalescence exhibited no abnormal changes.

DISCUSSION

Madding (3) and Sparkman (6) have comprehensively reviewed the wounds of the liver, including case presentations of their own which resulted from both penetrating and non-penetrating injuries. Their observation is that non-penetrating bursting injuries of the liver exhibited a far greater mortality rate, and the effectiveness of adequate control of hemorrhage and drainage are paramount to recovery.

Krieg (2) reviewed 60 mixed cases from our institution over a 7 year period in the pre-antibiotic era. The non-penetrating injuries presented a very high mortality primarily due to shock from blood loss. In the non-operative cases additional mortality resulted from bile peritonitis.

Sloan (5) and others (6) reported little change in the mortality rate of 78 per cent from bursting rupture of the liver since Edler's (1) compiled series of 543 cases in 1887. The associated injuries are common and may help account for the increased mortality.

Pringle (4), in 1908, advocated temporary occlusion of the vascular bundle to control massive bleeding due to liver injuries. Animal experiments at that time revealed congestion and swelling of the bowel after this procedure, but in the animals that recovered there were no evident changes. The following case illustrates this useful procedure and we suggest its employment whenever it is indicated:

A 21 year old man was admitted to the hospital on 6/12/57, after sustaining abdominal injury in an auto accident. Blood pressure was 130/90. There was diffuse tenderness of the entire abdomen with no bowel sounds being present. A four quadrant abdominal tap was performed without production of any diagnostic fluid. An hour later his pressure fell to 60/40 and another tap was productive of blood from the right upper quadrant. At operation a large, jagged stellate rupture of the anterior superior portion of the right lobe of the liver was found. The lacerated edge was sutured by deep running locking chromic catgut sutures. The contour of the liver was then reestablished by interrupted deep through and through sutures. Drains were placed, and the operation was terminated. Four hours postoperatively the patient was found in severe shock, with gasping respirations and massive bleeding from the drain site. He was returned to the operating room and re-explored through a thoracoabdominal incision. There was active bleeding from the sutured site. Blood pressure and pulse could not be obtained. It was necessary to occlude the hepatic artery and portal vein by placing an atraumatic clamp across the portal triad. There was an immediate cessation of bleeding from the fractured surface of the liver. The pressure promptly rose. Complete examination of the right lobe revealed a deep stellate laceration extending completely through the liver which was not sutured in the first operation. By intermittent releasing of the clamp across the portal triad it was possible to identify and suture a large tear in the portal vein. The arteries and veins on the torn surface were individually ligated. After the vessels had been ligated with the clamp in place, they were then further ligated after release of the clamp, making very careful hemostasis possible. Following this, large sutures of heavy swaged catgut were used to oppose the surface of the lacerated liver and eliminate potential dead space. The patient did well.

In severe ruptures of the liver, immediate control of bleeding is of utmost importance. If vision is obscured, the simple maneuver of compression of the portal triad may be life saving. During this period the patient's blood pressure is stabilized. After removing the accumulated blood, a thorough survey of the injured liver is possible. A more complete operation may be performed without haste. It is possible to individually ligate large bleeding vessels.

It is questionable whether gauze packs are helpful when one observes the large amounts of clotted and old blood seen during their removal. The complications which can follow packing of the liver may be numerous. Pressure necrosis of the already injured portion of the liver may be followed by profuse hemorrhage at a later time. This is frequently encountered when the packs have been tightly placed. The pack may act as a dam to prevent adequate egress of necrotic liver, old blood and bile. Space created by this packing must be adequately drained following its removal or abscesses and toxic reactions will follow from the collected material. In the already debilitated patient, any additional operative procedure and anesthetic may be poorly tolerated, and should bleeding occur at pack removal, the patient's ability to tolerate another operation may be poor.

The resection of primary and solitary metastatic tumors has given impetus to the often neglected possibility of debridement for ruptures of the liver. Obviously, no standardization for removing the injured segment can be advocated, but in selected cases this procedure can be useful in conjunction with temporary portal triad compression. Our own series reveals that debridement was performed twice. In one patient this was done on a delayed rupture 22 days after the initial injury; in another patient it was performed with removal of about 70 per cent of the right lobe after postoperative hemorrhage had continued.

In analyzing the 35 per cent mortality, it became evident that 71 per cent of those who died, died within a 45-minute to 16 hour period from uncontrolled hemorrhage. One wonders if the preponderance of deaths due to hemorrhagic shock could possibly have been modified by more frequent utilization of portal triad compression and adequate visualization through a thoraco-abdominal incision. We feel that this is important in light of the fact that the reported mortality from blunt non-penetrating bursting injuries of the liver is still unreasonably high.

SUMMARY

Twenty cases in which there had been a non-penetrating bursting rupture of the liver were reviewed. Complications are discussed and related to causes such as inadequate drainage, insufficient hemostasis or utilization of gauze packing. In a 35 per cent mortality, 71 per cent may have died from uncontrolled hemorrhage. Where bleeding is excessive, the injury great, and the blood pressure unobtainable, it is suggested that portal triad compression through a thoraco-abdominal incision be considered. Complete hemostasis and closure of the liver surface with adequate drainage is recommended.

REFERENCES

1. Edler, L. Die traumatischen Verletzungen der parenchymatosen Unterleibsorgane (Leber, Milz, Pankreas, Nieren). Archiv Fur Klinische Chirurgie, **34:** 343–409, 1887.
2. Krieg, E. G. Hepatic trauma. Arch. Surg., **32:** 907–914, May 1936.
3. Madding, G. H. Injuries of the liver. A.M.A. Arch. Surg., **70:** 748–756, May 1955.
4. Pringle, J. H. Notes on the arrest of hepatic hemorrhage due to trauma. Ann. Surg., **48:** 541–549, 1908.
5. Sloan, L. W. Injuries of the abdomen. In *Trauma*, edited by Harrison L. McLaughlin, pp. 495–539, W. B. Saunders Co., Philadelphia, 1959.
6. Sparkman, R. S. and Fogelman, M. J. Wounds of the liver: review of 100 cases. Ann. Surg., **139:** 690–719, May 1954.

BASKET TECHNIQUE FOR PRODUCING STANDARD THERMAL INJURY IN MICE

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The survival rate of scalded mice is an acceptable method for determining the effect of various chemical or biological agents on thermal injury. The standard technique is to anesthetize the animal and dip the lower two-thirds (up to the arm pits) in water at 70°C. for varying lengths of time. (2, 3, 4) This method, while serving well for acute experiments (up to three days), has certain limitations, particularly in chronic experiments. For example, the gangrene of the paws, tail, and scrotum, which is the rule following the above procedure, is a source of secondary infection. The possibility also exists that the urethral and anal orifices may be so injured as to be another source of infection and/or that the latter injuries may impede elimination. These complications obscure the issue being studied, namely thermal injury, and limit the effective time of the study.

The basket technique here described burns only the back of the animal (approximately 30 percent of the body surface) and has the following advantages: (1) there are no unrelated acute complications such as gangrene of paws, scrotum, or tail; (2) healing occurs under a closed scab or crust so that secondary infection is minimized; (3) chronic experiments may be carried on without unrelated chronic complications; (4) results are repeatable.

METHOD

A basket[3] made of stainless steel mesh (64 mesh) with a lid that can be secured firmly, was so constructed that the mouse fitted into it snuggly and was secured firmly by the lid which covered chest and abdomen only (Fig. 1). The basket is so shaped that the bottom accepts the curvature of the back of the animal, and the ends are tilted upwards so that urethral and anal orifices and tail on one end and the head on the other are at a level above the anterior axillary line of the mouse (Fig. 2). Lateral stainless steel arms project from the basket in such a manner and position that when the preparation is set into a water bath it remains fixed and the entire back of the animal up to the posterior axillary line is submerged in the water. From the two central arms, looped vertical handles project for grasping the basket (Fig. 1).

The water bath is composed of two sections. The inner section is a stainless

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[1] Statistical analyses by J. E. P. Libby and technical assistance by Alan B. Goodman.

[2] These studies were aided by Contract 101-161 (NR 114 161) between the Office of Naval Research, Department of the Navy, and the University of Illinois.

[3] Made by Edwin Herskind, 3847 North Janssen, Chicago 13, Illinois.

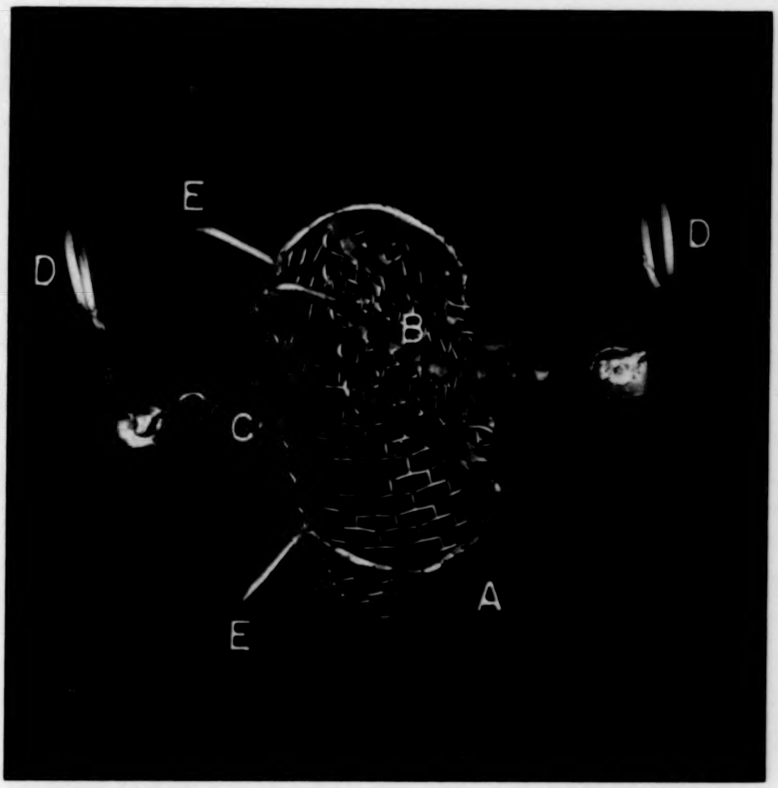


FIG. 1. *Basket with lid open.* Basket (A), lid (B), central lateral arms (C), loops for holding (D), and stabilizing arms (E).

steel beaker 3 inches in diameter and 4½ inches high which is slightly lipped. Three slots, 11/16 of an inch wide and 5/16 of an inch deep, cut out of the upper edge, allow for the overflow of water (Fig. 2). The beaker is suspended through an opening in a thin metal plate to which it is permanently fixed (Fig. 3). Lateral slots in the metal plate admit the central arms of the basket. The dimensions of the metal plate are such that it covers the upper edges of a standard water bath completely, thus avoiding vapors and heat issuing from the bath. A small opening caudal to the beaker admits the glass rod of a bulb-glass rod combination used to refill the beaker with hot water from the larger bath between each animal dipping. The water in the larger bath is circulated by a stirrer. The temperature of the inner section bath must be constant (± ½°C.) and regularly checked by the stationary thermometer.

The procedure used in this study was as follows. The mice were Swiss white males all purchased from one distributor and weighing from 18 to 22 grams

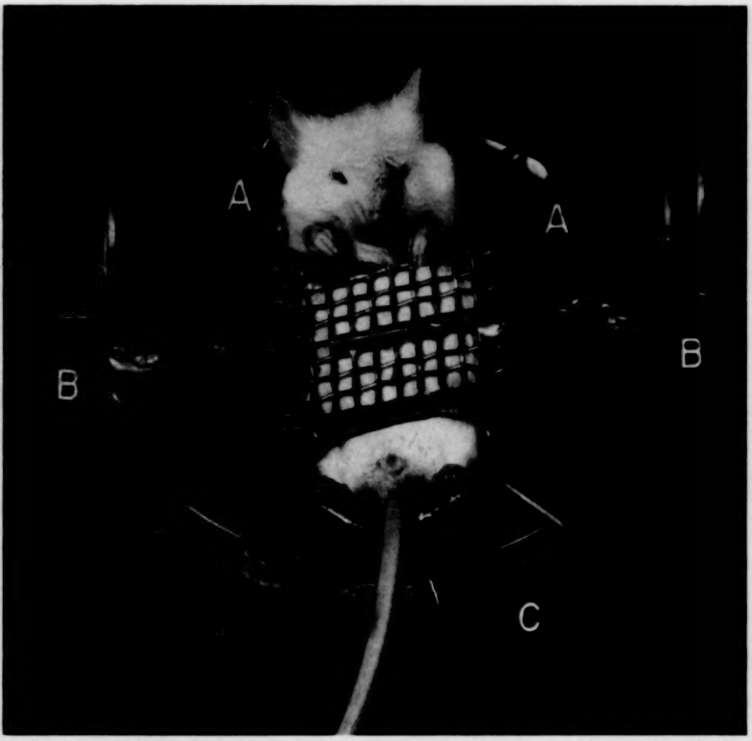


FIG. 2. *Basket with mouse in water bath.* Slots (A) in beaker are for overflowing; slots (B) in metal sheet (C) are for accepting lateral arms of basket. Note that ears, paws, anal and urethral orifices, and tail are above water line.

(before clipping hair) and chosen so that a randomization of weights was maintained within this range. The basket was made to fit a mouse this size snuggly after the hair of the back was shaved. Because of basket variations the same basket was used throughout. The temperature of the water bath was carefully adjusted to 70°C. (± ½°C.). The metal plate holding the beaker was adjusted to rest horizontally with the help of a carpenter's spirit level. The hair of the entire back of the mouse was clipped closely and carefully with a hair clipper (Oster head No. 40) just before scalding. The animal was placed in a glass jar containing a pledget of ether-soaked cotton which was covered by a wire mesh so that the ether-soaked cotton never touched the animal. When the respirations became slow and regular, the animal was removed and quickly placed in the basket and the lid closed, being sure that paws and ears were well above the lid and that tail, anus, urethra, and head were above the anterior axillary line. The basket was set into the inner water bath and the exposure timed with a stop watch. It is estimated that about 30 per cent of the body surface is thus burned. After scalding, the basket with the animal was removed and the animal

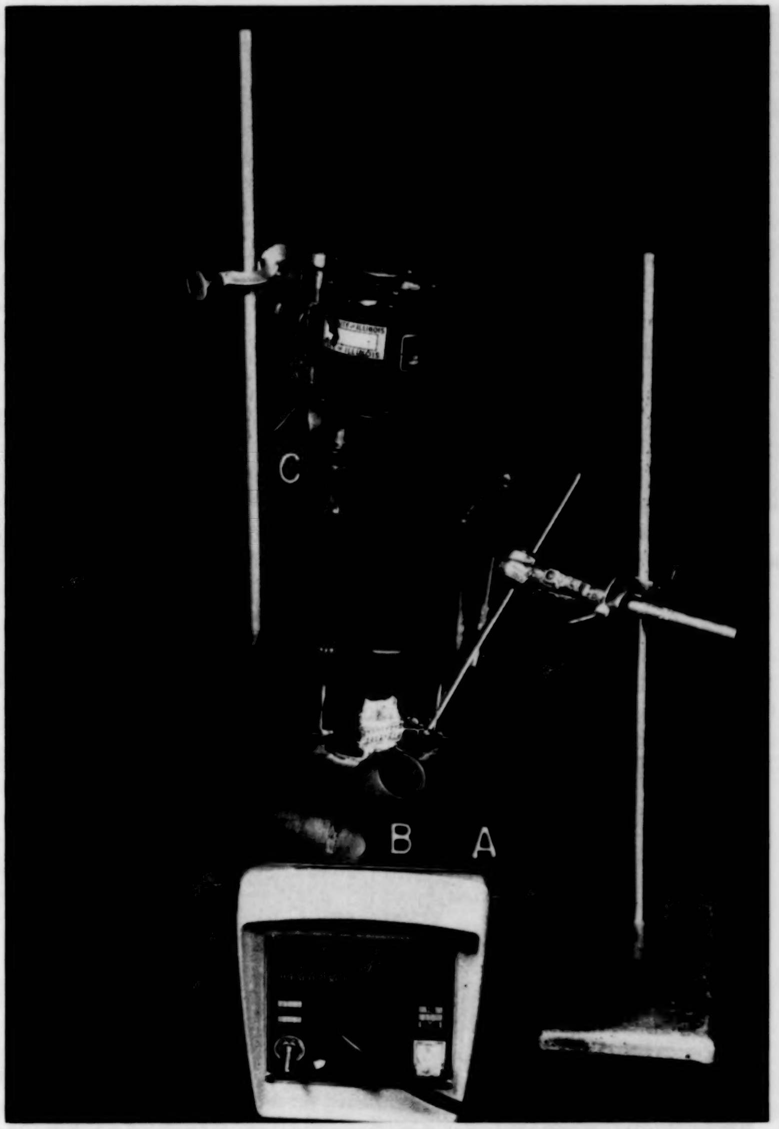


FIG. 3. *Entire apparatus with mouse in place*. Metal sheet (A) covering bath; bulb (B) for filling beaker with water between scaldings; stirrer (C).

quickly taken out of the basket and rolled on dry, absorbent paper. Water was added between each dipping to maintain the proper fluid level.

As a rule there were not more than five groups of ten mice each burned at one sitting. A control group of ten mice anesthetized and mock-burned was always included. Either ten mice were burned consecutively at a given time interval or the time interval was randomized, burning five animals at a time. The time intervals of scalding were varied from 6 to 10 seconds; only one experiment was done at 11 seconds.

The first 45 experiments representing 429 mice were performed from mid-May through the first half of August (spring-summer) when the outside temperatures varied from 47° to 93°F. The mice were scalded a day or two after they arrived from the distributor. When first received, they were kept in an individual unit type air-conditioned room (68° to 74°F.). They were then brought down to the laboratory which was not air-conditioned and remained there for one to two hours for the duration of the experiment after which time they were returned to the air-conditioned room.

The second group of 58 experiments representing 556 mice was performed during November and December (fall) when the outside temperatures varied from 28° to 49°F. These animals were housed and experimented upon in newly constructed animal quarters with centrally controlled air conditioning (temperatures 72° to 74°F.). The animals were acclimated to these rooms for one week before scalding.

After scalding, as described above, the animals were observed daily for up to 90 days. The nature of the local lesions and the mortality rates were recorded.

RESULTS AND DISCUSSION

Description of Lesions

For the first day following the scalding there were either no gross lesions of the skin or scattered small pinhead-sized red denuded areas. On palpation, a

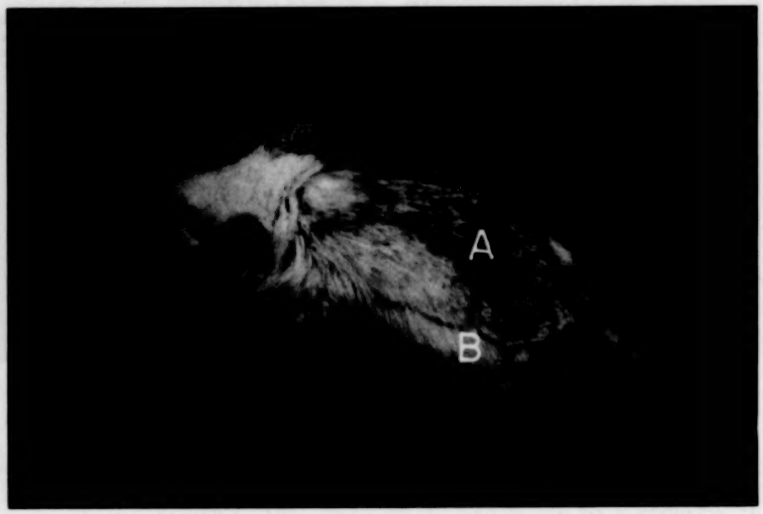


FIG. 4. *Mouse 8 days after burning (9 seconds at 70°C).* Note scab or crust (A) and sharp line of demarcation (B).

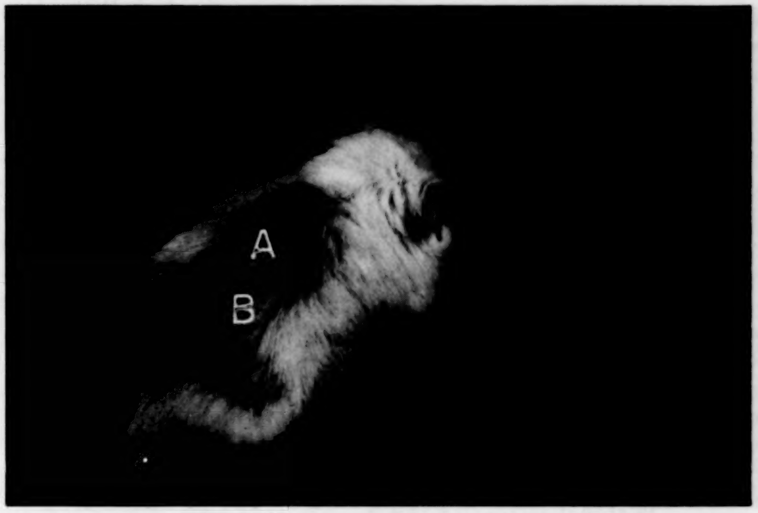


FIG. 5. *Mouse 30 days after burning (9 seconds at 70°C)*. The scab or crust has fallen off and there remains a thinly epithelialized skin (A) with a small denuded area (B).

TABLE I

Number of Mice and Experiments According to Duration of Scalding and Season of Year

Seconds of Scalding	Spring-Summer		Fall		Combined	
	No. of animals	No. of experiments	No. of animals	No. of experiments	No. of animals	No. of experiments
0	125	14	90	11	215	25
6	—	—	60	6	60	6
7	50	5	108	11	158	16
8	90	9	158	16	248	25
9	99	10	80	8	179	18
10	55	6	60	6	115	12
11	10	1	—	—	10	1
Totals..................	429	45	556	58	985	103

slight thickening of the injured area was noted. Gradually the skin became indurated and furrowed and was covered by the bristles of the base of the hair shafts not removed by the clippers. By the 7th to 10th day a continuous scab or crust formed with a definite line of demarcation (Fig. 4). At this time there were occasionally slight breaks in this crust, light to dark red in color. No evidence of discharge was observed. By the 25th to 30th day, the scabs or crusted areas fell off in sheets and as a rule left a thinly epithelialized skin with occasional small denuded lighter red areas (Fig. 5). From the 45th to 60th day there was restitution of the skin including hair, but the pattern of the hair was irregular.

Purulent discharge or suppuration was not noted. The healing proceeded under a scab by first intention so that smears or cultures were not taken. Complications not directly related to the scalding did not occur.

Mortality Rates

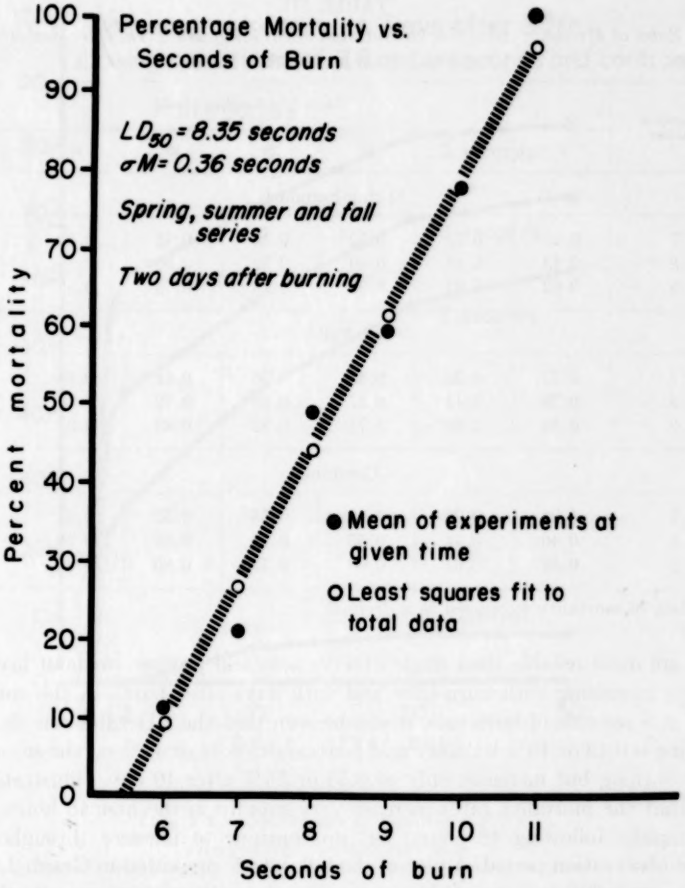
Table I shows the number of experiments done and the number of animals used at each burn-time for the spring-summer series (May 14 to August 12), fall series (October 28 to December 11) and combined series. Means and standard deviations were taken for all experiments at each burn-time, for each series, and for each observational day; those for one and two days after burning appear in Table II. The means for the spring-summer series do not differ from their fall counterparts at the 5% level of significance (28 comparisons). This finding indicates that the first series was confirmed by data taken in more controlled conditions, that meaningful data can be taken in the simpler installation, and that the two series may be statistically combined. From Table II it is noted that in the combined data two days after burning, the mean mortality for all experiments run at 8 seconds burn-time was 0.487 or 48.7% lethality. And in the same data the corresponding figure for 9 seconds burn-time was 0.594 or 59.4% lethality, illustrating that the LD_{50} must lie between 8 and 9 seconds. The higher mortality in burned animals as compared with controls was tested for significance by exact probability (1). P values were less than 0.001 throughout, indicating thermal injury is the major cause of death.

TABLE II

The Observed Mean Death Rates at 24 and 48 Hours of Scalded Mice For Varying Times of Burning

Day	6 Seconds		7 Seconds		8 Seconds		9 Seconds		10 Seconds		11 Seconds	
	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
Spring—Summer Series												
1	—	—	0.140	0.102	0.529	0.212	0.639	0.223	0.733	0.130	1.000	0.000
2	—	—	0.180	0.172	0.543	0.232	0.639	0.223	0.742	0.138	1.000	0.000
Fall Series												
1	0.117	0.090	0.181	0.187	0.398	0.281	0.500	0.200	0.733	0.189	—	—
2	0.117	0.090	0.227	0.198	0.460	0.312	0.538	0.173	0.817	0.177	—	—
Combined Series												
1	0.117	0.090	0.168	0.166	0.403	0.271	0.577	0.224	0.733	0.162	1.000	0.000
2	0.117	0.090	0.210	0.190	0.487	0.291	0.594	0.209	0.779	0.163	1.000	0.000

For number of animals see table I
M, Mean mortality expressed as a decimal
SD, Standard deviation
—, Not done



Data for spring-summer, fall, and the combined series were plotted in per cent mortality versus burn-time, one plot for each of these at 1, 2, 10, 20, 30, 60, and 90 days after burning. Since efforts had been made to confine burn times close to LD_{50}, these plots are essentially linear. Least-squares linear fit was applied to each of the 21 plots; a typical one is shown in Graph 1.

Analysis of variance was applied to each of these lines, comparing regression variance and deviation from regression variance. All values are significant. Spring-summer 90 day, and fall 60 and 90 day data give P values between 5% and 2%; spring-summer 20 day data show P between 1% and 0.1% (nearer latter); in all other cases $P < 0.001$. These P values indicate significant linear relationships in each fitting.

Table III gives mortality figures obtained from these least-squares lines. Because all data for a given observational day are used for each such entry,

TABLE III

Rates of Mortality According to Duration of Scalding and Time After Scalding

Derived from least-square lines

Seconds of Scalding	Days After Scalding						
	1	2	10	20	30	60	90
	Spring-Summer						
7	0.25*	0.27	0.32	0.45	0.45	0.50	0.64
8	0.43	0.45	0.49	0.59	0.60	0.65	0.76
9	0.62	0.62	0.66	0.73	0.76	0.80	0.87
	Fall						
7	0.23	0.26	0.43	0.56	0.61	0.68	0.68
8	0.38	0.43	0.57	0.69	0.72	0.76	0.76
9	0.54	0.60	0.71	0.82	0.83	0.85	0.85
	Combined						
7	0.23	0.27	0.42	0.55	0.57	0.63	0.66
8	0.40	0.44	0.55	0.66	0.69	0.73	0.76
9	0.58	0.61	0.68	0.77	0.80	0.83	0.85

* Rate of mortality expressed as a decimal

they are more reliable than single observations and progress without inversion, always increasing with burn-time and with days after burn. In the combined data at 8 seconds of burn-time it will be seen that the LD value one day after burning is 0.40 or 40% lethality and increases to 0.44 or 44% on the second day after burning but increases only to 0.55 or 55% after 10 days, illustrating the fact that the mortality rates increase very rapidly in the first 48 hours, much less rapidly following 48 hours, but do continue to increase throughout the entire observation period. A plot of the fall data is presented in Graph 2.

The gross shift in slope of these mortality plots at two days suggests that one phenomenon is operating in the first 48 hours after burning, while a separate factor of thermal injury appears to account for mortality beyond that time.

In the fall series, mortality of two day survivors was observed at 10 days in scalded and control animals. Similarly, 10 day survivors were observed at 20 days, and 20 day survivors were observed at 30 days. In each case, exact probability showed $P < 0.001$. This covers 7, 8 and 9 second burn times for each period (nine comparisons). This indicates mortality from scalding continues beyond 20 days.

A more specific purpose of this experiment was to determine LD_{50} values as guides to burn-time in future work; these are presented in Table IV together with the standard error of the mean of all experiments run at the burn-time nearest the LD_{50} in question. This measure of dispersion is appropriate for contemplated work involving one burn-time only. Fluctuations in standard errors are primarily due to differences in sample size. All figures are in seconds.

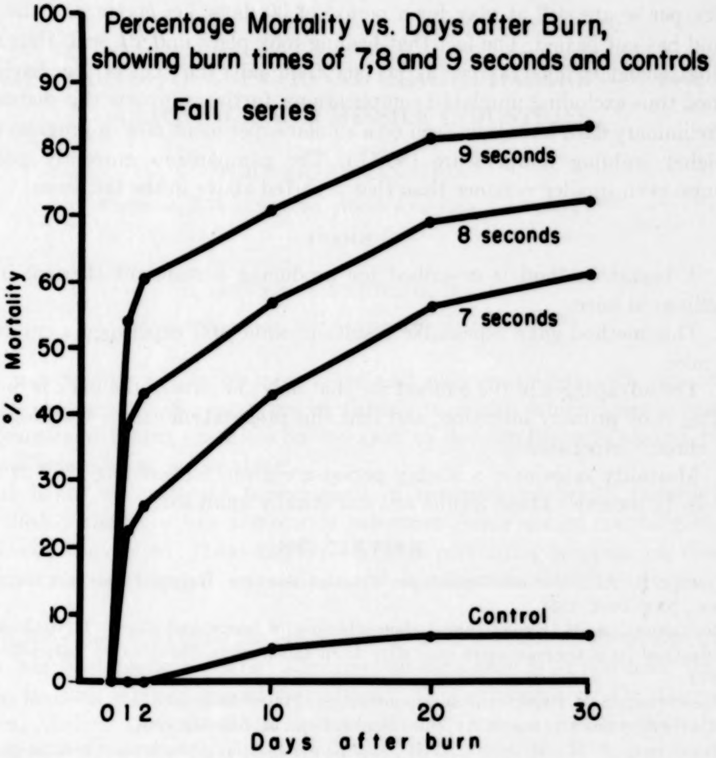


TABLE IV

LD_{50} Values in Seconds of Scalding (70°C.)

Derived from least-square lines.

Days After Scalding	Spring-Summer		Fall		Combined	
	LD_{50}	σ_M*	LD_{50}	σ_M	LD_{50}	σ_M
1	8.37	0.62	8.76	0.46	8.55	0.21
2	8.29	0.54	8.40	0.51	8.35	0.36
10	8.06	0.04	7.50	0.04	7.62	0.42
20	7.38	0.10	6.05	0.25	6.60	0.66
30	7.32	0.62	6.02	0.42	6.35	0.36
60	6.98	0.74	4.95	0.88	5.63	0.77
90	5.77	1.22	4.90	0.88	5.26	0.80

* σ_M is the standard error of the mean of the series nearest to the given LD_{50} in seconds.

The LD_{50} values in seconds of scalding (70°C.) under the conditions of these experiments varied with the days after burning. Thus at 1 and 2 days it is 8.55 (±0.21) and 8.35 (±0.36) seconds respectively (combined series) whereas at 30 days it is 6.35 (±0.36) seconds. It is deduced that the effects of the thermal injury per se are still at play for a period of 30 days, i.e., as long as the local wound has not healed. The fact that healing took place under a scab thus minimizing secondary infection, and the fact that only the skin of the back was burned thus excluding unrelated complications, further supports this deduction.

Preliminary data have been seen on a similar experiment now in progress using a higher scalding temperature (80°C.). The comparisons currently possible promise even smaller variance than that reported above in the fall series.

SUMMARY

1. A basket method is described for producing a standard thermal injury (scalding) in mice.

2. This method gave repeatable results in some 103 experiments embracing 985 mice.

3. The advantages of the method are that only the skin of the back is burned, healing is by primary intention, and that this preparation can be used for acute and chronic experiments.

4. Mortality rates over a 90-day period are given for scalding (70°C.) times of 6 to 11 seconds. These results are statistically analyzed.

REFERENCES

1. Fisher, R. A. *Statistical Methods for Research Workers.* Hafner Publishing Company, Inc., New York, 1958.
2. Rosenthal, S. M. Experimental chemotherapy of burns and shock. I. Methods. II. Effects of local therapy upon mortality from shock. Pub. Health Rep., **57:** 1923–1935, 1942.
3. Rosenthal, S. M. Experimental chemotherapy of burns and shock. III. Effects of systematic therapy on early mortality. Pub. Health Rep., **58:** 513–522, 1943.
4. Rosenthal, S. M., Millican, C. R., and Rust, J. A factor in human gamma globulin preparations active against pseudomonas aeruginosa infections. Proc. Soc. Exp. Biol. & Med., **94:** 214–217, 1957.

CONTROL OF OCCUPATIONAL HEALTH HAZARDS IN THE AEROSPACE AND MISSILE INDUSTRIES

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As man reaches out to conquer space and span continents with supersonic missiles, he encounters new types of threats to health which keep industrial physicians and health scientists on the alert to develop defenses against these hazards before harm can be done.

This paper will attempt to explain how occupational health hazards are controlled in the aerospace and missile industries. Some hazard control generalizations will be offered. These may be helpful in preventing occupational disease among personnel engaged in research and development activities in any industry.

"No substance is so toxic that it cannot be used if sufficient knowledge of its action has been made available; similarly, no substance is so non-toxic that it should be used without regard to caution." This statement by Dr. James A. Sterner, Medical Director of the Eastman Kodak Company, places the subject of occupational health hazards in its proper perspective.

Research and development activities related to aerospace, missiles and space vehicles involve complex technologies, and require the handling of a wide variety of materials, some of which are so new and unusual that they are referred to as "exotic." These "exotic" materials frequently find their way into experimental operations before their toxic properties have been fully investigated. In addition, many purchased products of a proprietary composition are received for evaluation by the engineer. He cannot always obtain specific toxicological data on the product or its components. Material compatibility studies may also create potential health hazards.

Because of time limitations only a few of the more unusual materials of a hazardous nature encountered in the aerospace and missile industries will be mentioned. These include propellant fuels such as liquid ammonia, hydrazine, unsymmetrical dimethylhydrazine, liquid hydrogen, the boron hydrides and beryllium. These fuels may be used in combination with any of the following oxidizers such as ozone, liquid fluorine, concentrated hydrogen peroxide, red fuming nitric acid and nitrogen tetroxide.

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Toxic manifestations can result if these materials are inhaled, ingested, or are allowed to come into contact with the skin. The Committee on Threshold Limits, American Conference of Governmental Industrial Hygienists has established threshold limit values for control of health hazards from inhalation of toxic substances. These values are reviewed yearly with changes or additions made at the annual meeting of the group. Often these changes result from industrial experience, since industry in reality is a huge laboratory for experimentation with materials. For example, the first published threshold limit value for carbon tetrachloride was 100 parts per million. The large number of occupational disease cases arising from the use of this material in industry resulted in the lowering of its threshold limit to 25 parts per million. These values were formerly known as MAC's (maximum allowable concentrations). They are maximum average in-plant atmospheric concentrations of contaminants to which workers may be exposed for an eight-hour working day without injury to health. It cannot be over-emphasized that these values are to be used only as guides in the control of health hazards. They should not be regarded as fine lines between safe and dangerous concentrations. How much these figures may be exceeded for short periods during the work day depends upon such factors as the nature of the contaminant, whether high concentrations even for short periods can produce acute poisoning, whether the results are cumulative, the frequency with which high values occur and for what periods of time, as well as variability in individual susceptibility. Established values for gases are expressed as parts of contaminant per million parts of air by volume or simply ppm, those for toxic dusts, fumes, and mists as milligrams of material per cubic meter of air (35.3 cubic feet).

An interesting concept for comparison of effective toxicity of volatile compounds is that of the Hazard Index proposed by Dr. W. H. Schechter of the Callery Chemical Company. The Hazard Index is a function of both toxicity and vapor pressure. It is obtained by dividing the vapor pressure of the material by the LC_{50} or concentration in parts per million necessary to kill 50 per cent of exposed test animals. This simply means that given two substances of equal toxicity the one with the lower vapor pressure will present less of an inhalation hazard. Conversely, a material with a low threshold limit, but high volatility, may be more hazardous to handle than one with low volatility and higher toxicity.

The highly complex nature of the aerospace and missile industries requires a team-work approach to the control of occupational health hazards. Many disciplines are called upon for contributions in the solution of control problems. A typical operation may involve a team consisting of the industrial physician, the industrial nurse, the industrial hygiene engineer, the safety engineer, the project engineer, a toxicologist, a human factors specialist, a meterologist, and possibly outside consultants. As soon as the details of the control program are worked out, the information is disseminated in written form through supervision to the working level.

Some companies are using the committee approach to prevent occupational disease and to minimize all hazards that might be encountered in research and development operations. This committee may be called a technical hazards committee or exposure evaluation committee. The committee staff normally consists of a limited number of engineers, no more than one from each laboratory group. These engineers are chosen because of their diversified experience and combined they represent all major areas of laboratory activity. Committee membership is rotated every three months. The committee does not conflict with the plant safety committee or with supervision. Close liaison is maintained between the committee and the industrial physician, the fire department, the safety engineer, the industrial hygienist and outside consultants. Safe operating procedures are developed and published in a controlled circulation manual. The primary functions of the committee are to point out hazardous conditions that are not generally obvious in research and development operations, to develop safety consciousness on the part of the individual engineer and technician, and to devise safe handling techniques and procedures for hazardous materials. The committee should have the power to shut down any hazardous operation.

Where possible, inhalation hazards are eliminated or minimized by use of local ventilation or respiratory protection in the form of masks or air supplied respirators. Skin contact is prevented by use of protective clothing such as gloves, boots or suits. Current models of protective suits require modification to make them impervious to many of the propellant fuels and oxidizers, light weight, low cost, flexible, rugged, well ventilated and cooled so that the user will remain comfortable for periods up to six hours. Ingestion is prevented by strict adherence to good personal hygiene.

Constant air monitoring is carried out to determine whether worker breathing zone air concentrations do not exceed threshold limits. With respect to this latter point, there is a real need for reliable, sensitive, quantitative, low cost, portable instrumentation for the detection and estimation of highly toxic substances, such as beryllium and the borane hydrides. The threshold limit value for beryllium for an eight hour daily average exposure is 2 micrograms per cubic meter of air; whereas, that for pentaborane, one of the boron hydrides, is 0.005 parts per million. Beryllium fines are solids without any distinguishing odor, and pentaborane is a colorless, volatile liquid that has an odor threshold of 2.5 parts per million. Inhalation of as little as 50 micrograms of beryllium has been known to cause beryllium disease in humans and repeated 5 hour daily exposures to 3.3 parts per million of pentaborane has caused death in test animals. These examples are cited merely to illustrate the fact that we frequently have more knowledge of the toxicology of materials than we do of the means for detecting low levels in air.

It is well recognized that prevention is the best cure for disease and it is axiomatic that prevention of occupational health hazards can be achieved through a program of education and medical management combined with industrial hygiene and engineering controls. The following are offered as prevention fundamentals for occupational health hazards:

(1) If a known hazard exists, determine the degree of exposure to the haz-

ardous environmental conditions and the possible effects on the health of the worker.

(2) Set up and maintain the specific control measures indicated.

(3) Make definite assignment of responsibility for all phases of the preventive program.

(4) Contact State, Federal or local qualified agencies for technical assistance relating to occupational health hazards.

(5) Make definite provision to insure that occupational health hazards involved in the use of new substances or techniques, changes in processes or work methods, will, in each instance, receive advance consideration for proper prevention and control.

(6) Insist on complete toxicological evaluation of all vendor supplied proprietary items. Do not accept nebulous statements from salesmen made without foundation in fact.

(7) Before claiming that a health hazard exists, one must have the following facts:

(a) The nature of the substance or physical condition involved.

(b) The intensity of exposure.

(c) The duration of exposure.

The horse and buggy days of occupational health have drawn to a close. No single individual or discipline can cope with all of the complexities of modern technicological developments. Physicians contribute materially in this teamwork approach to the control of occupational health hazards. This involves careful selection of working personnel and the establishment of the mental and physical standards for the preplacement examination, as well as the medical surveillance program for specific toxicants in conjunction with improved environmental control and personal equipment.

An example of how well this teamwork control approach has worked is the virtual elimination of acute beryllium disease in industry.

It is hoped that this short presentation has provided some insight into the methods employed in the aerospace and missile industries to safeguard not only the employee but the community at large.

REFERENCES

1. Breslin, A. J. and Harris, W. B.: Health Protection in Beryllium Facilities, Summary of Ten Years of Experience, HASL 36—New York Operations Office. Health and Safety Lab. A.E.C. May 1, 1958, pp. 62.
2. Comstock, C. C., et al: Inhalation Toxicity of Hydrazine Vapor., Chemical Corps Medical Laboratories Research Report No. 253, Army Chemical Center, March 1954.
3. Division of Occupational Health, Los Angeles City Health Department, Los Angeles, California; Safe Handling Practices for Magnesium-Thorium Alloys, October 1958.
4. Environmental and Occupational Health Information Letter No. 13; Toxicity of Products of Thermal Decomposition of Teflon., Headquarters Air Material Command Wright-Patterson Air Force Base, Ohio, Office of the Surgeon, September 1957.
5. Gray, LeB., et al: Acute Inhalation Toxicity of Nitrogen Dioxide, Red Fuming Nitric Acid, and White Fuming Nitric Acid., Chemical Corps Medical Laboratories Research Report No. 282, Army Chemical Center, Maryland, May 1954.

6. Jacobson, K. H., et al: The Acute Toxicity of the Vapors of Some Methylated Hydrazine Derivatives., A.M.A. Arch. Indust. Health, **12:** 609–616, December 1955.
7. Krop, S.: The Toxicity and Health Hazards of Rocket Propellants., Jet Propulsion, **24:** 223–227, 236, 1954.
8. Lowe, H. J. and Freeman, G.: Boron Hydrice (Borane) Intoxication in Man., A.M.A. Arch. Indust. Health, **16:** 523–533, 1957.
9. Nasatir, A. V.: Industrial Health Hazards of the Aircraft Industry, Division of Industrial Hygiene, Los Angeles City Health Department, Los Angeles, California, May 1941.
10. Nuttal, J. B.: Toxic Hazards in the Aviation Environment. J. Aviation Med. **29:** 641–649, 1958.
11. Griffin, W. G. and Hosey, A. D.: Occupational Health Hazards. Their Evaluation and Control. U. S. Dept. of Labor. Bureau of Labor Standards. Bulletin No. 198, (Washington, Government Printing Office, 1958) pp. 36.
12. Office of the Assistant Secretary of Defense, Research and Engineering Advisory Panel on Fuels and Lubricants: Liquid Propellant Safety Manual., The Liquid Propellant Information Agency, Applied Physics Laboratory, The Johns Hopkins University, Silver Spring, Maryland, October 1958.
13. Schechter, W. H.: Gather Safety Know-How in Boron Handling., Ind. Labs. **9:** 6–8, 1958.
14. Stumpe, A. R.: Health Hazards of New Aircraft and Rocket Propellants. A Review of Literature, J. Aviation Medicine, **29:** 650–659, 1953.
15. Threshold Limit Values for 1960. American Conference of Governmental Industrial Hygienists. A.M.A. Arch. Environ. Health. **1:** 140–144, 1960.
16. Dill, B. and Jacobson, H.: "Toxicity of Propellant Fuels and Oxidizers". Presented April 28, 1959 at 30th Annual Meeting of the Aero Medical Association, Los Angeles, California. Abst. in Aerospace Med. **30:** 182, 1959.
17. Larouche, L. P.: Future Materials and Propellants.
18. Larouche, L. P.: "Special Health Problems at Cape Canaveral." Presented at 30th Annual Meeting of the Aero Medical Association, April 28, 1959, Los Angeles, California

THE EFFECT OF AGE ON THE VASCULAR RESPONSE TO FRACTURE

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INTRODUCTION

The responses of the vascular system to fracture have been incompletely documented. Handicapped by crude techniques, the earliest investigators were limited to the visual impression that following the fracture of a long bone in a dog, there was a very considerable increase in the size and number of vessels surrounding the healing fracture (2).

Working with plastic injection techniques, Wray and Lynch have recently been able to demonstrate an increase in volume of the vascular bed of the entire lower extremity of the rat following fracture of the ipsilateral tibia (3). This volume increase rises to a peak at 9–12 days following fracture and then gradually resolves toward control levels with healing of the fracture. From an analysis of more recent data the evidence is accumulating that several factors may influence the evolution of this vascular hypertrophy. Age might reasonably be expected to be one of the more important of these factors.

The healing potential of the infant is vastly greater than that of the senile individual. This fact is particularly evident in any clinical study of fracture healing. On the other hand, the vascular bed enlargement that follows fracture of a long bone in the experimental animal may not parallel the healing process and may remain constant throughout life. This study was carried out to determine if postfracture vascular bed hypertrophy differs in senile and infant rats and to define these differences if they exist.

MATERIALS AND METHODS

Female rats of the C. F. Nelson strain were used in this study. All animals were housed in metal cages in groups of ten and were maintained on a standard laboratory diet. Three different groups of rats were utilized. In the first group the animals were six weeks of age at the start of the experiment and were classified as infants. The second group of animals were four months of age at the beginning of the experiment and were considered "adults." Animals of the third group were approximately two years of age. These rats were originally obtained from a Walter Reed colony; and had been maintained as a senile rat colony at the Bowman Gray School of Medicine for over fifteen months.

In all animals other than those used for controls, a closed fracture of the left tibia was produced by finger manipulation under ether anesthesia. The fractures

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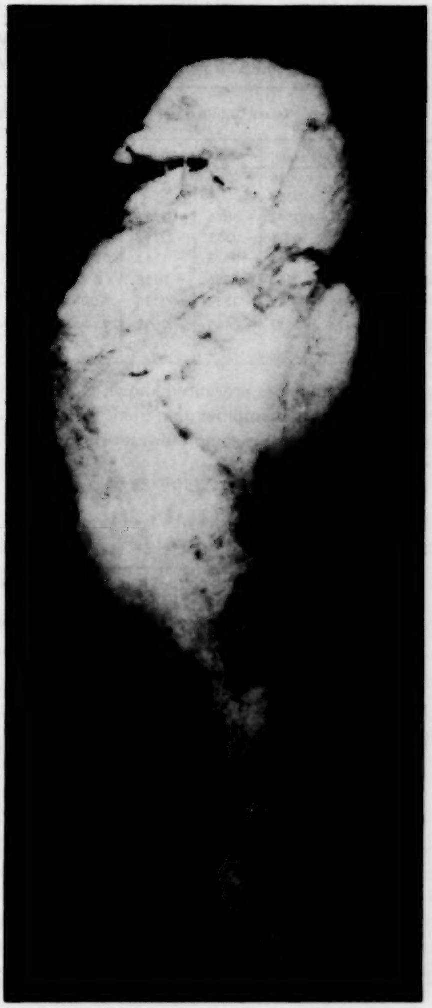


FIG. 1. After injection of the trunk and lower extremities of the rat, the plastic is allowed to harden and both hind limbs disarticulated at the hip. After disarticulation both limbs are immersed in a 5% solution of KOH for 72 hours and a 30% solution of HCL for 24 hours to remove all animal and mineral matter. A plastic cast of the vascular bed of the entire limb remains. A typical specimen is reproduced above.

were not immobilized and all were x-rayed after death of the animal. Animals with incomplete fracture or in whom breaks occurred in the skin were not included in the final analysis.

The plastic injection technique used in this experiment has been described in detail elsewhere (3). At stated intervals following fracture the animal is killed

TABLE I

DATA OBTAINED FROM INFANT, ADULT AND SENILE RATS
(Total 373 Animals)

Days After Fracture	No. of Animals			Means Of Differences			Probability That Control And Experimental Means Show A Difference Due To Chance Alone		
	Infant	Adult	Senile	Infant	Adult	Senile	Infant	Adult	Senile
Controls	23	21	27	+.0088	+.0027	+.0274			
3	17			-.0059			<.3>.2		
6	15	15	14	+.0342	-.0093	+.0389	<.1>.05	<6>.5	<.7>.6
9	15	16	16	-.0221	-.0368	-.0786	<05>.02	<.2>.1	<.001
12	13	17	16	-.0312	-.0816	-.1113	<02>.01	<.01>.001	<.001
15	15	16	16	-.0168	-.0358	-.1056	<.2>.1	<2>.1	<.01>.001
18	17	16	15	-.0371	-.0562	-.0396	<.001	<.1>.05	<.05>.01
24	17	19	17	-.0197	-.0468	-.0599	<.1>.05	<.05>02	<.01>.001
Totals	132	120	121						

The basic data from the experiment is presented above. Note that all three Groups have their own controls. Some irregularity in number of animals for any specific date has resulted from discarding animals on the basis of incomplete fractures, death, etc. Only completely acceptable animals are included in this data.

TABLE II

MEAN DIFFERENCES OF INFANT, ADULT, SENILE RATS COMPARED

Days After Fracture	Infant VS Adult		Infant VS Senile		Adult VS Senile	
	T	P	T	P	T	P
Controls	0.44363	<.7>.6	1.2889	<.3>.2	1.08906	<.3>.2
6	1.9333	<.1>.05	.17172	<.9>.8	1.6355	<.2>.1
9	.59274	<.6>.5	2.4533	<.05>.02	1.6379	<.2>.1
12	2.122	<.05>.02	2.6461	<.02>.01	1.0780	<.3>.2
15	.7698	<.5>.4	2.5014	<.02>.01	1.9356	<.1>.05
18	.82398	<.5>.4	.10993	>.9	.56790	<.6>.5
24	1.3382	<.2>.1	1.6314	<.2>.1	.53732	<.6>.5

Comparison of the mean differences of senile, adult and infant Groups produced the results presented here. It is apparent that significant differences between infant and senile rats are present at 9, 12 and 15 days postfracture.

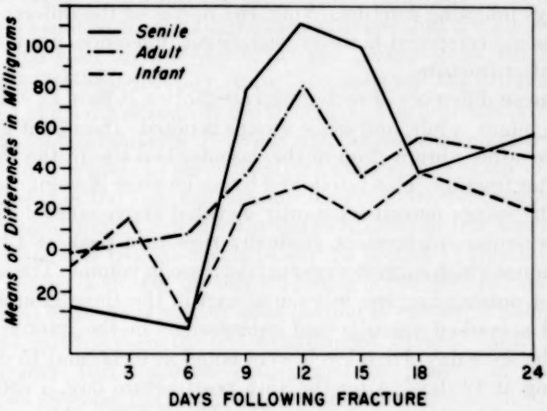
Note: It is recognized that in making 21 comparisons one would expect to find at least 1 significant difference at the .05 level due to chance alone. Since four were found instead of one more credence can be put in the meaningfulness of these differences. (Consulting Statistician)

with an overdose of ether and the thoracic aorta is cannulated with a polyethylene catheter attached proximally to a closed system of three-way stopcock and saline filled syringe. After a stab wound is made in the right ventricle the vascular system is flushed with normal saline until the return flow through the right ventricle is clear. A syringe filled with liquid methyl methacrylate (with catalyst and promoter added) is then attached to the stopcock and the hind limbs and lower trunk of the animal are injected with plastic which is allowed to harden.

Both hind limbs are then disarticulated at the hip and chemically digested in

CHART 1

Vascular Bed Hypertrophy in the Fractured Limbs of Senile, Adult and Infant Rats



When the mean differences of senile adult and infant rats are plotted as a graph, dramatic variation is noted in the vascular bed enlargement response. As shown above, volume changes are much more dramatic in the senile animals as contrasted to the infant group.

a 5% solution of KOH for 72 hours followed by a 30% solution of HCL for 24 hours. At the completion of digestion only, the plastic mold of the vascular bed of the entire limb remains (Fig. 1). The mold is allowed to dry at room temperature and is then weighed with an analytical balance scale. The weight of the plastic mold of each limb is compared with the weight of the mold of the opposite paired member.

RESULTS

Data obtained from a total of 373 rats was included in the final analysis and is shown in Table I.

Of the 133 "infant" rats, 23 were used as controls. There were 21 controls in 120 "adult" animals and 23 controls in the senile group of 120 animals. The experimental animals of each group were subdivided into approximately equal groups to be sacrificed at 6, 9, 12, 15 and 24 days after fracture. An additional 17 rats in the infant classification were sacrificed at three days.

The means of the differences between plastic casts of paired limbs for each group are given in the center columns while the probability of observing a mean difference by chance alone if no difference actually exists is presented on the right of Table I.

A probability level of .05 was considered statistically significant in this experiment. Significant vascular bed enlargement occurred at 9, 12 and 24 days after fracture in the adult group. On the other hand, significant enlargement developed in the senile group nine days after fracture and persisted throughout the remainder of the experiment.

The mean differences of infant, adult and senile rats are compared in Table II. There were no significant differences between the means of adult and senile rats, whereas a significant difference existed between the means of adult and infant rats at 12 days following fracture. When the means of the differences of infant and senile rats are compared however, significant differences are noted at 9, 12, and 15 days after fracture.

When the mean difference of each group are plotted (Chart I), a dramatic contrast between infant, adult, and senile groups is noted. The infant group is characterized by a rather abrupt drop in the vascular bed size of the fractured limb at six days after fracture. This is followed by an increase in volume at nine days, after which the values remain constantly elevated above control values. In the adult group vascular enlargement gradually rises to a peak at 12 days and is followed by values which suggest a gradual decrease in volume. The senile animals show the most outstanding rise in volume seen in the three groups. These rats demonstrated a marked vascular bed enlargement in the fractured limb that began after the sixth day. High levels were noted at 9, 12, and 15 days with the peak appearing at 12 days. After the 15th postfracture day, a drop in volume occurred that may be due to sampling error. This is followed by a greater value at 24 days.

DISCUSSION

Several phenomena contribute to the vascular response to fracture. Within minutes of fracture of the tibia in a series of dogs, a marked increase in blood flow into the limb was noted. Possibly as a result of a similar response and other, as yet unknown factors, a gradual enlargement of the vascular bed occurs in the fractured limb of the experimental rat. This volume increase reaches a peak at approximately 9 to 12 days following fracture and then appears to subside gradually with healing of the fracture. The pattern of this response in the rat shows a constant relationship to the trauma of fracture when repeated refractures are produced at the original fracture site. In addition, repeated refracture has been found to lead to progressive enlargement in the vascular bed.

In 1922, Lexer produced visual evidence of postfracture vascular bed enlargement by injecting a mixture of turpentine and mercury into the vascular system of the fractured hind limb of the dog. On the other hand, he lacked experimental techniques to measure blood flow and failed to suspect increased flow into the limb as a factor in the production of vascular bed enlargement.

After a series of experiments in which he qualitatively estimated the extent of vascular bed enlargement, Lexer concluded that the process was the same in youth and old age. In direct disagreement with Lexer's observations, the data obtained in this experiment is quantitative in nature and demonstrates significant differences between the enlargement process in youth and old age. It should be noted, however, that this study has made no effort to evaluate any possible blood flow differences between senile and infant animals.

It seems likely that postfracture vascular bed enlargement is basically a passive phenomenon, occurring at least in part, in the venous system. Evidence to support this concept is furnished by this study for the differences demonstrated here might be explained by certain intrinsic changes that are known to occur in the vascular tree with age. In youth, arteries possess great elasticity and the veins relatively little distensibility. With increasing age the arteries become less elastic and the veins develop great distensibility. Much greater volume changes occurred in the senile animals in this study and suggest that postfracture vascular bed enlargement is related to the capacity of the venous system to distend.

The relationship of the vascular volume changes to fracture healing is far from clear at the present time. Certainly the data obtained in this experiment fail to demonstrate a parallel relationship between the process of fracture healing and vascular bed enlargement. On the other hand, it is possible that the two may be inversely related with the relatively slow healing of the senile animal associated with relatively greater vascular bed enlargement. Recent work performed by Judet (2) suggests that hypervascularity may be present in some nonunion fracture calluses and may have some significance here. On the other hand, definite conclusions regarding vascular-healing relationships would not seem to be justified in this study for several reasons. First, no critical effort was made to evaluate the extent of fracture healing in the animals and second, the post-fracture observation period was not prolonged enough to permit conclusions regarding the duration of the process.

The decrease in vascular volume noted to occur in the infant rats at six days after fracture has also been seen in a comparable series of four week old rats when it was found to reach the level of statistical significance. The exact pathogenesis of this volume decrease is not clear at this time, but it seems possible that it may be related to temporary resistance to increased inflow on the part of relatively poorly distensible infant vascular bed.

CONCLUSIONS

1. Vascular bed enlargement in the involved limb occurs after fracture of the tibia of infant, adult and senile rats.

2. There are significant differences in the vascular bed enlargement following fracture of infant rats as compared to that of senile rats and of infant rats as compared to adult animals.

3. It is likely that observed differences between infant and senile rats are due to vessel distensibility changes known to occur with increasing age. On the other hand, this study has not ruled out the possibility of an inverse relationship between the rate of fracture healing and the extent of the vascular bed enlargement.

BIBLIOGRAPHY

1. Clark, J. H. The elasticity of veins. Am. J. Physio. **105:** 418-427, 1933.
2. Judet, R. Nonunion of fractures (Work presented at the Eighth Congress of the Inter-

national Society of Orthopaedics and Traumatology, Sept. 1960, New York).

3. Lexer, E. Uber die Entstehung von pseudarthrosen nach frakturen und nach knochentransplantation. Arch. F. Klin. Chir., 1922, **119:** 520–607, 1922.
4. Wray, J. B. and Lynch, C. J. The vascular response to fracture of the tibia in the rat. J. Bone & Joint Surg. **41-A**, 1143–1148, 1959.
5. Wray, J. B. and Spencer, M. P. The vasodilatory response to skeletal trauma. Surgical Forum **11:** 444–445, 1960.
6. Wray, J. B. The Vascular Response to Repeated Fracture. Surg., Gynec. and Obst. **112:** 421–424 1961.

EARLY OPERATION, A CONSERVATIVE APPROACH TO THE TREATMENT OF CHRONIC IRRADIATION INJURY

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Tissue traumatized by excessive and often unwarranted radiation undergoes a progressive alteration which leads to local tissue necrosis, extensive fibrosis, painful ulceration, abnormal epithelial proliferation, and occasionally malignancy. After it has begun, the inexorable course of chronic irradiation injury can be interrupted only by surgical intervention. This includes the removal of all involved tissue, followed by adequate reconstruction utilizing uninvolved tissue often from a distance.

Unfortunately, the surgical treatment of such chronic irradiation injury is fraught with complication. The intense fibrosis, local ulceration, indolent infection, and reduced vascularity which are the constant companions of progressive radiation damage produce severe problems in wound healing that frequently complicate any form of operative therapy. As experience with this lesion has increased, it has become apparent that the earlier this progressive lesion is treated, the simpler the management, and the better the ultimate prognosis.

PATHOGENESIS

When radiation is utilized as a diagnostic instrument, or as a mode of therapy, or received through accidental exposure, some degree of damage, even though slight, will occur in the local region subjected to the ionizing beam. Permanent progressive injury, however, occurs only in those individuals who may be unduly sensitive, or have received heavy doses of radiation, either as a single exposure, or through multiple small exposures, the cumulative effect of which produces an excessive total dose.

Wolbach (7) describes five stages in the progressive development of chronic irradiation injury:

1. Loss of skin appendages.
2. Replacement of collagen by hyaline connective tissue rich in elastic fibers.
3. Obliterative processes in blood vessels, involving both the arterial and venous systems.
4. Necrosis, particularly of the corium.
5. Epithelial proliferation as a healing response to the necrosis within the corium.

Brown (1) suggests that the obliterative processes in the vascular tree may begin with the venous and arterial elements and may result in the telangiectasia which universally accompanies irradiation damage.

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Teloh (6) amplifies the proliferative stage of irradiation reaction and describes further stages of epithelial differentiation which occur as the injury pursues its inexorable course:

"1. Simple irradiation reaction of the skin.
2. Varying degrees of dyskeratosis and dysplasia.
3. Carcinoma in situ.
4. Localized invasion of malignant epithelium.
5. Wide spread carcinoma."

Although the exact mode of action of ionizing radiation within the individual cell is subject to considerable argument, there is little doubt that the ultimate fate of the damaged cell is death from failure of cell replacement (2, 6).

This process of cellular destruction is universally accompanied in the involved tissue by atrophy, fibrosis, and marked reduction of vascularity (4). The resulting devitalized tissue then falls easy prey to minimal trauma, or superficial infection which in the absence of normal inflammatory response may produce the indolent, painful ulceration so characteristic of advanced radiation disease (1, 3).

CLINICAL MATERIAL

A review of our experience with chronic irradiation injury treated at the University of Kansas Medical Center over the past 14 years yielded 169 cases with an overall surgical complication rate of 39% (Table I). Although the surgical complications varied from poor healing to fatal hemorrhage, the high incidence of postoperative difficulty demanded a critical reappraisal of the methods of management. All cases were reviewed in terms of:

1. Postoperative complications
2. Stage of the disease
3. Time interval from exposure to treatment
4. Method of treatment.

The comparison and analysis of the data thus obtained form the basis of this report.

POSTOPERATIVE COMPLICATIONS

Although the numerical incidence of surgical complication in the treatment of chronic irradiation injury was high, the extent of postoperative difficulty was quite variable. Ranging from prolonged healing to massive fatal hemorrhage, the most common postsurgical problems appeared to be directly related to the diminished blood supply, lowered tissue vitality, and excessive fibrosis present in the radiologically damaged wounds (4) (Table II).

Five deaths occurred in this series which could be directly attributed to the surgery of chronic irradiation injury. Two patients died of massive hemorrhage from surgical exposure of the carotid artery through irradiated tissue which then failed to heal and rupture of the artery occurred. Two succumbed to systemic spread of Staphylococcus aureus, and one death occurred from infection and inanition caused by a large radiation slough of the abdominal wall, compounded by an attempt at surgical reconstruction.

TABLE I

Complication Rate for the Treatment of Irradiation Injury

Severity of Injury	Number of Cases	Number of Complications	Per Cent
Radiodermatitis	77	15	19%
Radiation Ulcer	92	50	54%
Total	169	65	39%

TABLE II

Post-Operative Complications

	Number of Cases
Prolonged Healing	11
Infection	11
Partial Loss of Split-Thickness Skin Graft	26
Complete Loss of Split-Thickness Skin Graft	2
Partial Loss of Pedicle Graft	12
Complete Loss of Pedicle Graft	1
Fatal Hemorrhage	2

STAGE OF THE DISEASE

Since chronic irradiation damage is a slowly progressive degenerative process, the varying clinical manifestations seen at the time of surgical therapy represent different stages of the same process rather than separate and distinct lesions occurring spontaneously. Categorically, the clinical manifestations were divided into two major groups; 1. radiodermatitis representing the earlier stage characterized by atrophy, telangiectasia, fibrosis, and keratosis but with an intact surface epithelium; 2. radiation ulcer representing the progression of the degenerative process to include tissue breakdown, infection, and malignant degeneration.

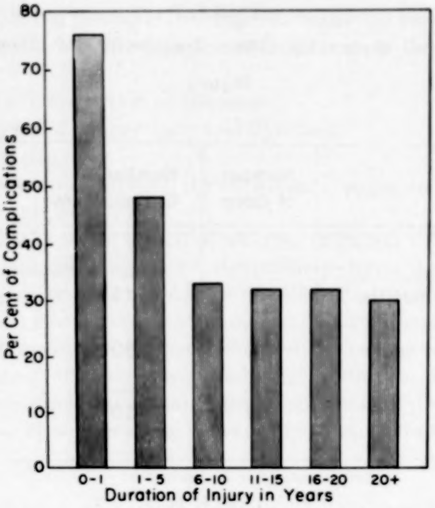


FIG. 1

The complication rate shows an impressive difference when these two stages are compared (Table 1). If therapy is instituted after the epithelial covering of the injured area is broken, the complication rate rises rapidly. This would indicate that surgical therapy earlier in the course of the process accompanied by a much lower complication rate is the procedure of choice.

TIME INTERVAL BETWEEN EXPOSURE AND TREATMENT

Several factors influence the time interval between exposure to radiation and the treatment of its untoward results. Such variables include the original dosage, the so-called "lag period" between irradiation and its cumulative effect, and the progressive increase in symptomatology which finally forces the patient to seek clinical advice. It would seem that the longer the duration of time between injury and treatment, the higher the surgical complication rate but such is not the case (Fig. 1).

The highest incidence of postoperative difficulty occurred in those cases treated within one year of exposure. The early onset of clinical symptoms requiring surgical therapy represents an acute process resulting either from massive cancercidal dose, or abnormal sensitivity to radiation. This figure suggests that surgical therapy for an acute radiation reaction is extremely hazardous.

The severe surgical problems in patients with acute radiation reaction is further demonstrated when the stage of the process is compared to the time interval between exposure and treatment (Fig. 2). With one exception, every patient who sought therapy within the first year following exposure had already progressed to ulceration, and attempts at surgical reconstruction were accompanied by an ap-

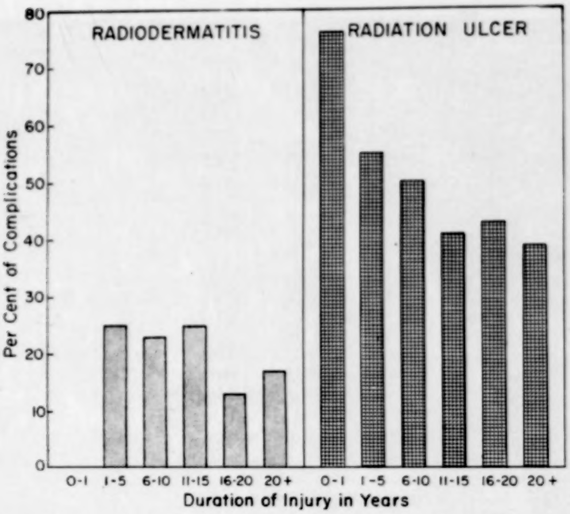


FIG. 2

palling rate of postoperative difficulty. If, however, treatment could be instituted while the degenerative process remained local, the incidence of complication was considerably less. Irradiation reaction, regardless of duration should be treated prior to ulceration.

METHODS OF TREATMENT

The surgical management of chronic radiation damage depends primarily upon the extent, the stage, and the location of the lesion. Brown (1) has emphasized the necessity of removing the entire area of involvement, which in the majority of instances will require some form of local reconstruction either by split thickness skin grafting or by transfer of a pedicle graft. Occasionally, however, block resection will be required when underlying bone is involved.

The comparison of the various types of surgical management to their complication rate shows that the simplest methods of treatment produce the lowest percentage of postoperative difficulty (Fig. 3). If, however, these methods are reevaluated in terms of the stage of the disease, the simpler surgical techniques are the procedures of choice before there is local tissue breakdown, but with advanced change, the more complex methods of reconstruction are required and, despite their complexity and multiplicity of stages, the pedicle reconstruction and block resection techniques carry a lower surgical complication rate (Fig. 4).

Thus, if the symptom complex of chronic irradiation injury can be treated early in the progressive stages of the disease, simpler procedures are required, and the more conservative methods of management become the treatment of choice.

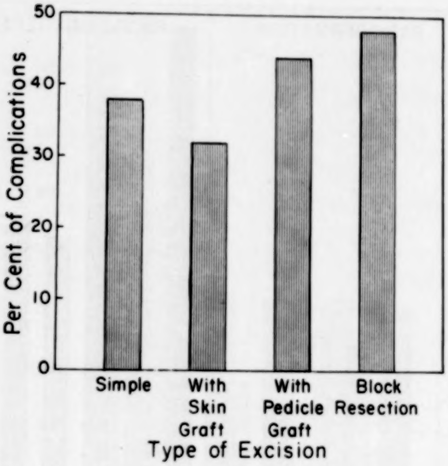


FIG. 3

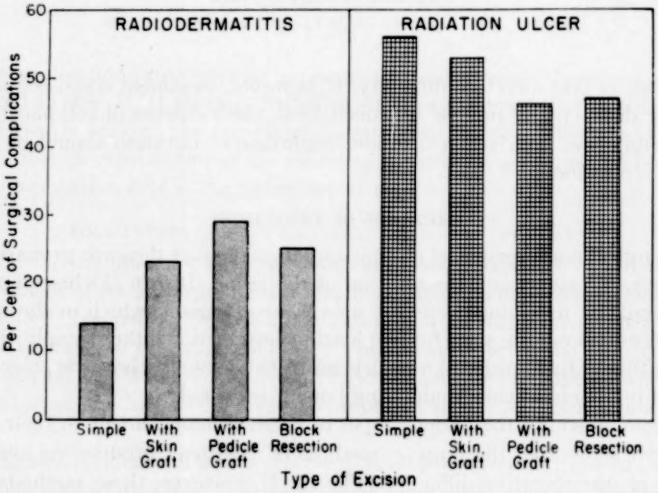
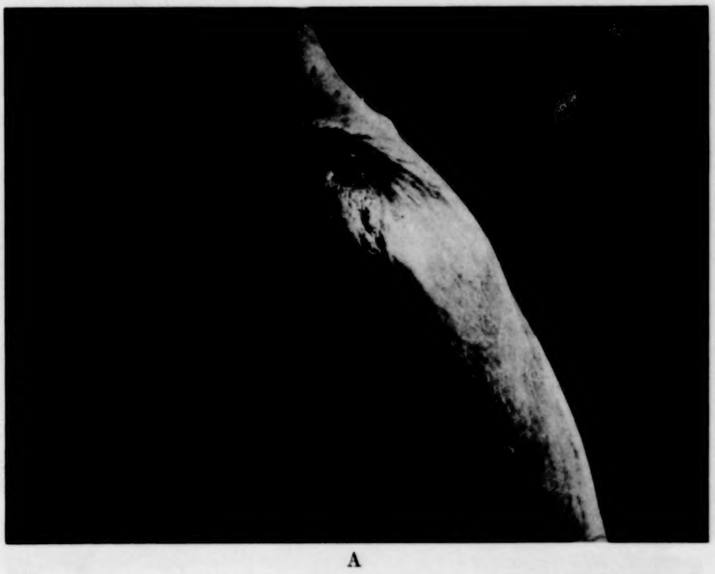


FIG. 4

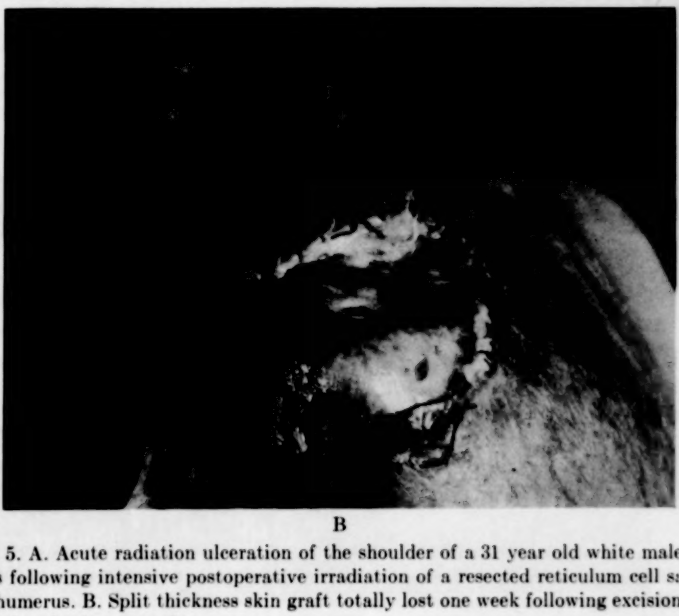
DISCUSSION

Although the critical analysis of postoperative difficulty is a chastening experience, certain clinical facts become quite apparent as a result of this investigation which may help to further reduce the incidence and degree of complication, and at the same time improve the overall results of the therapy of chronic injury.

1. Chronic irradiation injury is a progressive disease which pursues an inexorable course from atrophy to malignancy and the only therapy is total excision of

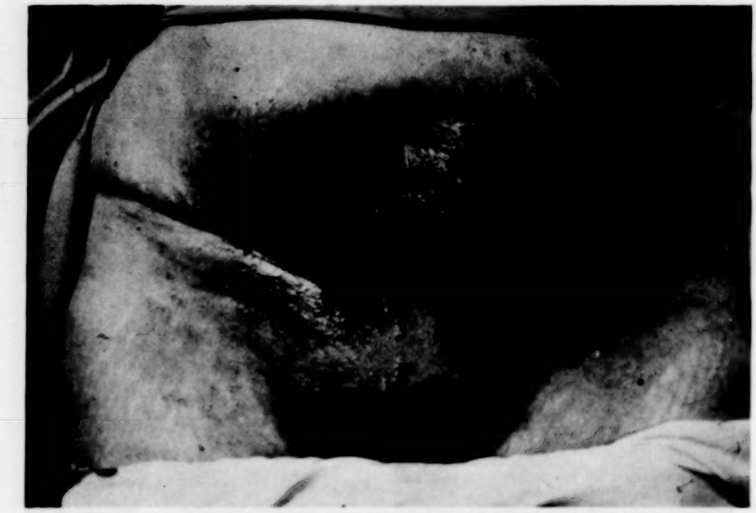


A



B

Fig. 5. A. Acute radiation ulceration of the shoulder of a 31 year old white male seven months following intensive postoperative irradiation of a resected reticulum cell sarcoma of the humerus. B. Split thickness skin graft totally lost one week following excision of the ulcer bed and primary graft.



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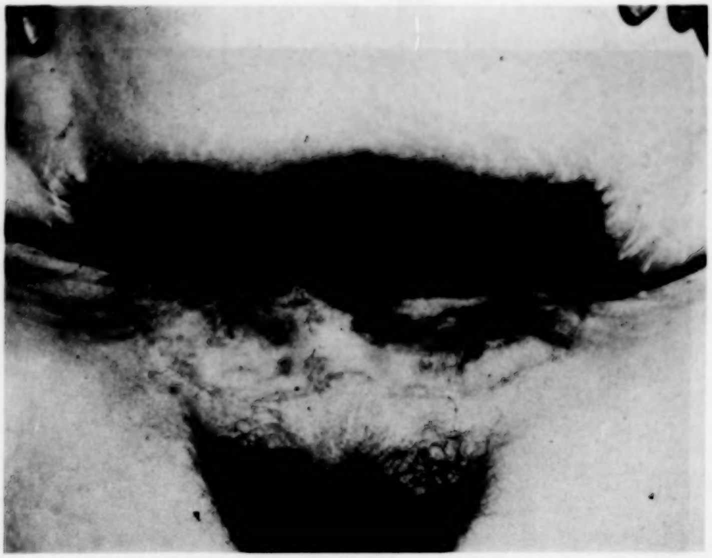

B

FIG. 6. A. Extensive chronic irradiation injury without ulceration of the lower abdominal wall of a 49 year old female, eleven years following irradiation therapy for carcinoma of the cervix. B. Postoperative photograph shows a complete resurfacing of the defect, two months following excision to a good bleeding base and primary split thickness skin graft.

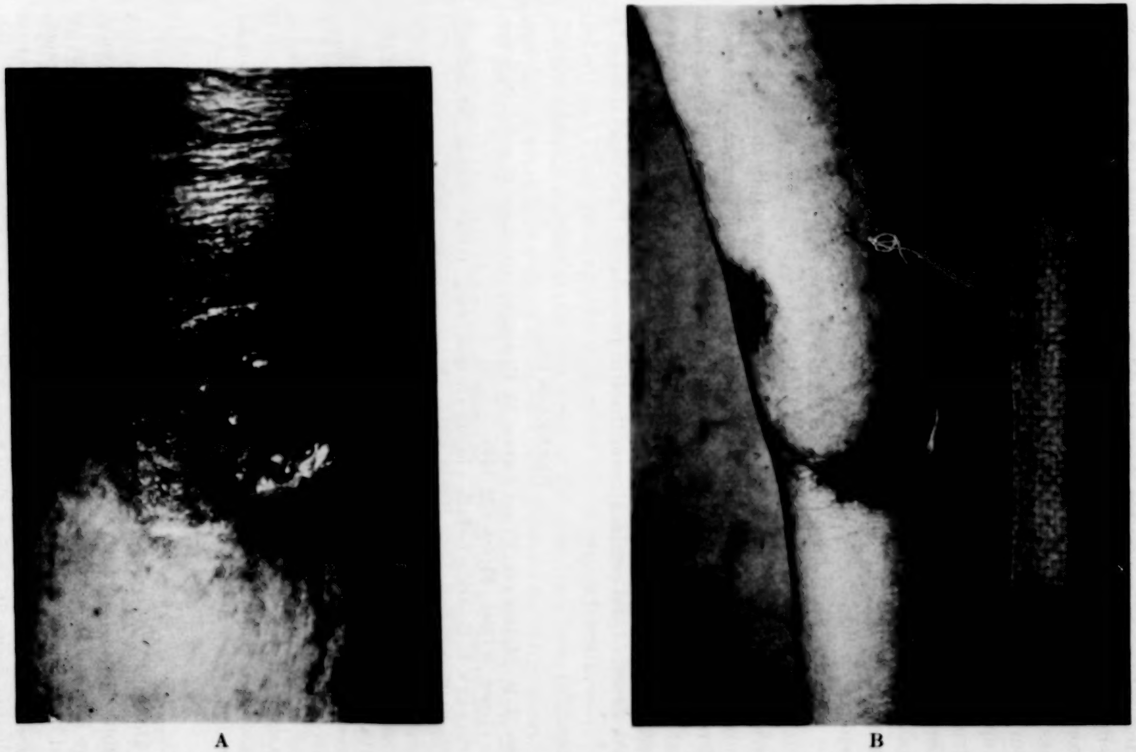

FIG. 7. A. A 63 year old white female developed an ulcer over the anterior tibia with exposed bone one year after the intensive irradiation of a squamous cell carcinoma of the skin. A previous excision and split thickness skin graft had failed. B. Postoperative appearance, two months following excision and rotation of a pedicle graft.

the lesion, followed by reconstruction utilizing either local or distant healthy, radiologically uninvolved, tissue (1, 5).

2. Surgical intervention during the acute phase of radiation reaction is accompanied by an almost prohibitive incidence of postoperative difficulty and whenever possible, operation should be avoided until the acute reaction has subsided (Fig. 5).

3. During the earlier stages of the chronic disease, prior to local tissue breakdown, operative intervention carries an optimum risk and simpler methods of reconstruction become the procedures of choice (Fig. 6).

4. When tissue breakdown occurs, the more radically destructive and the more complex reconstructive procedures take precedence (Fig. 7). The complication rates, though still high, are significantly lower than with the simpler methods of management.

SUMMARY

Experience with 169 cases of all varieties of irradiation injury indicates that early surgery, except in acute radiation injury, can abort the inexorable progression of radiation damage. Simple excision, combined with split thickness skin grafting, early in the course of the chronic disease will relieve symptoms, reduce postoperative difficulty, and prevent late clinical complications that require more radical destructive and complex reconstructive procedures. Early operation is in reality conservative therapy.

REFERENCES

1. Brown, J. B., McDowell, F. and Fryer, M. P. Surgical treatment of radiation burns. Surg., Gynec. & Obst., **88:** 609–622, 1949.
2. Hempelmann, L. H. Acute radiation injuries in man. Surg., Gynec. & Obst., **93:** 385–403, 1951.
3. Lewis, S. R. Management of radiation injuries. Am. Surgeon, **18:** 842–850, 1952.
4. Robinson, D. W. The hazards of surgery in irradiated tissue. A.M.A. Arch. Surg., **71:** 410–418, 1955.
5. Robinson, D. W. and Masters, F. W. Surgery for radiation injury. A.M.A. Arch. Surg., **80:** 946–952, 1960.
6. Teloh, H. A., Mason, M. L. and Wheelock, M. C. Histopathologic study of radiation injury of the skin. Surg., Gynec. & Obst., **90:** 335–348, 1950.
7. Wolbach, S. B. Summary of effects of repeated roentgen-ray exposures upon human skin, antecedent to formation of carcinoma. Am. J. Roentgenol. **13:** 139–143, 1925.

DISCUSSION

Dr. Donald M. Glover (Cleveland, Ohio): I had the opportunity to go over the manuscript of the paper by Drs. Masters and Robinson and it is indeed a pleasure to discuss their contribution on a subject in which I have long been interested but not very productive. I could not agree more with their major tenet, which is, in simple terms, to replace the normal skin covering of progressive areas of irradiation dermatitis before they become malignant.

It is very difficult to distinguish the benign from the malignant in this process except by microscopic section. They have described aptly the inexorable course of irradiation injury to which I alluded in comparable terms in a contribution before this Association in 1947.

Basically there is little difference between irradiation damage with malignant ulceration from that which results from long-standing heat burns, with the single exception that irradiation dermatitis is accompanied by perivascular round cell infiltration which produces the impaired vascularity to which Dr. Masters has alluded in his paper.

Fortunately, however, there is enough vascularity to make free grafts practical in most instances.

Another significant item is that all areas of irradiation damage seem to be infected, even though not ulcerated, which leads us to encourage antibiotic prophylaxis in all instances where such areas are replaced by skin grafts of any type. Some of our graft losses have resulted from failure to use antibacterial agents.

Dr. Masters reports five deaths in his series. We had only one fatality even remotely connected with the process, and that was a patient whose situation got out of hand while I was overseas during the war, and died from complications secondary to chemotherapy employed elsewhere.

Perhaps the difference rests with the number of patients in his series who were treated by heavy irradiation for malignant disease, primarily. We have been very conservative about doing skin replacement in such cases until enough time has elapsed so that we felt quite sure that the original malignant lesion was controlled, and I am speaking now in terms of ten or fifteen years.

A considerable number of our own series of 250 cases have been followed for at least fifteen years, and some of them have been followed for thirty years. By far the majority have resulted from the treatment of benign lesions from 20 to 30 years prior to our first observation. Some of our patients received some of the first external x-radiation given in New York about 1895, and several of those are still living and apparently free of disease at 80 to 85 years of age.

We have observed a few instances in which, after years of removing multiple lesions, most commonly on the face, the skin appears to have become more stable, and seems to have lost its tendency to become malignant.

I should like to ask Drs. Masters and Robinson if they think this is possible, or if they regard irradiation damage to the skin as initiating a process which continues inexorably throughout the lifetime of the patient.

Thank you.

President Stack: Dr. Masters, do you have any closing remarks?

Dr. Frank W. Masters (Kansas City, Kansas) (Closing): In answer to Dr. Glover's question, we too have seen long periods of relative quiescence in the irradiation reaction. However, we feel that it is just that, rather than a period in which they are apparently getting well, and that the process itself is actually inexorable.

Dr. Brown, in his monograph, makes the statement that irradiation injury will progress from atrophy to malignancy if the patient lives long enough, so apparently most people feel that it is an inexorable process.

I would like to clear up one other point, and that is, in this series, massive hemorrhages occurred actually while operating through irradiated tissue, but usually the reason for the operation was recurrence of malignancy. Since no further irradiation could be given, and we felt that we had to do something, we operated through previously irradiated tissue, much to our regret.

I do want to express my appreciation to Dr. Glover for his kind discussion.

Thank you.

PATTERNS OF THORACIC INJURIES IN FATAL TRAFFIC ACCIDENTS

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In the metropolitan New Orleans area most traffic accident victims are hospitalized in a single institution, Charity Hospital. Furthermore, all victims of fatal accidents are autopsied in Charity Hospital or in the coroner's office. This centralization of patient and autopsy records provides material for analysis on a uniform basis of all traffic accident victims in the area. The present study is a statistical analysis of causes of death in such victims over a five-year period, with particular emphasis on patterns of thoracic injuries in fatal accidents.

MATERIAL

This study covered a five-year period, from May 1, 1954 through April 30, 1959. During this time there were 585 deaths from traffic accidents in the metropolitan New Orleans area. Approximately 80% of all the victims requiring hospitalization were admitted to Charity Hospital. All victims were autopsied in the Orleans Parish coroner's office or Charity Hospital. Of this group 294 victims demonstrated significant thoracic injuries, and 133 were considered to have died primarily as a result of thoracic injuries. Of this latter group, 54 patients survived the accident and gained hospital admission. The present statistical analysis was derived from hospital records and autopsy protocols.

OBSERVATIONS

Rib Fractures: Of the 585 traffic victims, 230 (40%) had one or more fractured ribs. Of these, 103 were believed to have died primarily as a result of thoracic trauma. One hundred and twenty-three cases with rib fracture had associated hemothorax. In only 48 of 230 cases with rib fracture was there no significant intrathoracic injury (Table I).

Sternal Fractures: There were 29 cases of sternal fracture, and all but two of these had other major thoracic injuries (Table II). Of these victims, 15 died before reaching the hospital. Twenty-five had rib fractures, ten had heart or great vessel lacerations, and five of the victims sustained rupture of the diaphragm.

Hemothorax: Of 161 cases of hemothorax, 48 victims had no demonstrable intrathoracic injuries. Rib fractures were the most commonly associated injuries, and the great vessels and lungs were the most commonly injured organs causing hemothorax.

The contents of this paper reflect the personal views of Dr. Kemmerer and are not to be construed as a statement of official Air Force policy.

* Instructor in Surgery.

TABLE 1

Thoracic Injuries Sustained in 585 Traffic Fatalities

Finding	Number of Cases	Per Cent
Rib fractures	230	39
Hemothorax	161	28
Lung laceration	60	10
Ruptured great vessel	58	10
Lung contusion	35	6
Lacerated diaphragm	30	5
Sternal fractures	29	5
Myocardial laceration	22	4
Myocardial contusion	11	2
Lacerated trachea	5	1
Lacerated esophagus	1	.2

TABLE II

Thoracic Injuries in 29 Cases of Sternal Fracture

Rib fractures	24
Great vessel and/or heart laceration	10
Diaphragmatic rupture	5

Lung Laceration: Lacerations of the lung at autopsy were found in 60 victims, 34 of which died before reaching the hospital. Others may have had smaller lacerations which healed or were obliterated by adhesions prior to death.

Diaphragmatic Laceration: This injury was observed in 30 cases. It was usually associated with crushing injuries of the chest, abdomen, or pelvis and was frequently related to other severe intrathoracic injuries. Of these 30 cases, nine had thoracic great vessel lacerations and four had heart lacerations. Twenty-four patients died before reaching the hospital. In four cases there was no apparent significant trauma to the thoracic cage or abdomen (Table III).

Injuries of the Trachea and Esophagus: The trachea was ruptured in five instances and the esophagus in only one of the 585 traffic victims. In four of the five cases of tracheal laceration, rib fractures were present and in three of the five, great vessel lacerations occurred. One patient sustained a heart laceration and one, a sternal fracture. Of the victims with tracheal laceration, four were dead at the scene of the accident. The other survived the accident but died following an attempt at repair of the resultant tracheal stenosis. The single patient with esophageal laceration died prior to hospitalization.

Myocardial Contusion: This finding was noted in 11 patients, only one of which did not live to gain hospital admission. The injury was noted in only one case with associated fracture of the sternum. Only two individuals had no other major thoracic trauma.

Myocardial Laceration: Of the 22 victims who died with myocardial lacerations, 19 had rib fractures and four had sternal fractures. Other chest injuries associated

TABLE III

Thoracic Injuries in 30 Cases of Ruptured Diaphragm

Crushed chest	16
Crushed abdomen or pelvis	10
Great vessel laceration	9
Sternal fracture	5
Heart laceration	4
Lung laceration	4

TABLE IV

Site of Laceration of the Heart in 22 Cases

Right ventricle	9
Not specified	6
Left ventricle	2
Right atrium	2
Left atrium	2
Right and left ventricle	1

with the cardiac lacerations included ruptured great vessels in 11, lacerated diaphragm in two, and lung lacerations in five. All but two of the victims died immediately following the accident. Laceration of the right ventricle, the most common site of rupture, was found in nine cases. The left ventricle was the site of laceration in two cases, the right atrium in two, the left atrium in two, and the right and left ventricle in one. In six cases, the exact site was not indicated (Table IV).

Lacerations of Great Vessels: Lacerations of the intrathoracic great vessels were found in 58 victims. Forty-seven of these did not live long enough to reach the hospital. The average length of life in the hospital was 3½ hours, excluding one patient who developed a dissecting aneurysm of the thoracic aorta and lived 18 days.

Of the victims with lacerations of the great vessels, rib fractures occurred in 36, fracture of the sternum in 8, rupture of the diaphragm in 10, laceration of the heart in 10, and laceration of the lung in 9.

The aorta was the most frequently injured of the intrathoracic great vessels. This occurred in 46 cases; in nine cases it was associated with injuries of other great vessels or the heart. The aorta was injured in various sites along its intrathoracic course. The most common site was immediately distal to the left subclavian artery.

In five cases the superior vena cava was lacerated; in seven, the intrathoracic inferior vena cava; in four, the pulmonary artery; in five, the pulmonary vein, and in one, the innominate artery. In seven of the 11 cases of laceration of the superior or inferior vena cava, other great vessels or the heart were injured. In five of the nine cases of pulmonary artery or vein laceration, other great vessel or heart injury was present (Table V).

TABLE V

Location of Thoracic Great Vessel Injury in 58 Cases

Thoracic aorta	46
Inferior vena cava (thoracic)	7
Superior vena cava	5
Pulmonary vein	5
Pulmonary artery	4
Innominate artery	1

DISCUSSION

In this series of 585 victims of traffic accidents, 23% died as a result of chest injuries, and 50% were found to have severe injuries to the thoracic area. Rib fractures occurred in 40% of all traffic victims, and almost half of these died as a result of chest injuries. Fractures of the sternum occurred infrequently, but this injury was associated with a high incidence of severe underlying injuries. In 13 of the 29 cases of sternal fractures, great vessel, diaphragmatic, or heart lacerations were present singly or in combination. Fractures of the sternum also were frequently associated with rib fractures.

Laceration of the heart occurred in 22 cases. Of these, two individuals survived long enough to gain hospitalization. One patient underwent splenectomy but died a few hours later as a result of pericardial tamponade from a lacerated myocardium. The other patient underwent thoracotomy three hours following admission, at which time a laceration of the right pulmonary vein and atrium was repaired. However, he died 12 hours post-operatively in irreversible shock.

Of the 58 cases with lacerations of the great vessels, 11 patients survived long enough to gain hospital admission and have initial diagnostic procedures; in eight the diagnosis was missed. Two of the patients with lacerations of the aorta lived three and four hours. One walked into the hospital. Another developed a dissecting aneurysm and lived 18 days. One patient died as a result of a torn superior vena cava, having lived 7½ hours in the hospital; another patient died as a result of a torn pulmonary vein, three hours after admission.

The diagnosis of ruptured diaphragm was missed in two of the six victims gaining hospital admission. Both of these patients underwent exploratory celiotomies for suspected abdominal visceral injuries. Injuries of the trachea were infrequent in this series, and four of the five such victims were dead before arriving at the hospital.

Although the majority of traffic accident victims in this series did not survive to reach a hospital, a significant number gained hospitalization and died subsequently. Misdiagnosis, delay in diagnosis and improper or delayed treatment appeared to be especially frequent in patients with injuries of great vessels.

SUMMARY

1. The causes of death were analyzed in 585 traffic accident victims occurring in a 5-year period in the metropolitan New Orleans area.

2. Of 585 victims, 294 had significant thoracic injuries, and 133 were considered to have died as a result of thoracic trauma.

3. Rib fractures occurred in 40% of all traffic accident victims. Approximately 80% of cases with rib fractures showed significant intrathoracic injuries.

4. Sternal fractures were frequently associated with serious intrathoracic injuries. Only 2 of 29 such patients showed no other major thoracic injury. Great vessel, diaphragmatic or heart laceration occurred in 13 of 29 cases with sternal fractures.

5. Myocardial contusion was observed in 11 cases, 10 of which reached the hospital alive. However, among 22 victims with myocardial lacerations, only two reached the hospital alive.

6. Lacerations of the intrathoracic great vessels occurred in 58 cases; eleven of these victims reached the hospital alive, and in eight patients the diagnosis of great vessel injury was missed.

ANALYSIS OF FACTORS AFFECTING SURVIVAL AFTER CHEST INJURIES

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Despite extensive literature pertaining to thoracic injuries additional information regarding the overall survival of patients with these injuries should be helpful. Large series of penetrating wounds based on military experience have been reported but in many ways these are not comparable to injuries seen in civilian practice. Non-penetrating thoracic injury, particularly that resulting from vehicular accidents, carries a high mortality, and it would be desirable to have more information as to the fate of patients sustaining these injuries. Many reports are concerned primarily with modifications of treatment, description of unusual injuries or series of specific intrathoracic injuries (1, 2, 3, 5). This report is a review of all cases of trauma to the chest admitted to the Tulane Surgical Service, Charity Hospital of Louisiana, during the period from July 1953 to July 1958. The results are analyzed to determine factors which affect survival.

PENETRATING INJURIES

Two hundred and sixty-five patients with thoracic injury were admitted during this period (Table I). Of these, forty-one died, an overall mortality of 15 per cent. There were 158 who had sustained penetrating wounds, eleven of whom died; a mortality of 7 per cent. Among these there were forty with gunshot wounds, five of which were due to shotgun blasts and 35 to pistol shot. One hundred and three patients were stabbed with knives, eight with ice picks, and there were seven penetrating injuries due to miscellaneous agents. The mortality rates resulting from knife or bullet wounds were 7 and 6 per cent, respectively. There was one fatality among five shotgun wounds, but no death occurred from ice-pick injuries.

EXTENT OF INTRATHORACIC INJURY

Most of the patients were treated without operation so it was not possible to ascertain how many had penetration of the chest wall alone or injury to the underlying lung (Table II). It is possible also that in some patients injury to other structures was not recognized. Irrespective of the mechanism of injury, 138 patients presented only hemothorax, pneumothorax or combination of the two. Four patients in this group died, a mortality of 2.8 per cent. One of the four had

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TABLE I

Thoracic Injuries 1953–1958 (Tulane Surgical Service Charity Hospital of Louisiana)

	Cases	Deaths
Penetrating injury	158	11 (7%)
Non-penetrating injury	107	30 (28%)
Total	265	41 (15%)

TABLE II

Penetrating Injury of Thorax

Injury	Cases	Died
Lung and chest wall*	138	4 (2.8%)
Heart	14	5 (35%)
Great vessel	2	2 (100%)
Intercostal and internal mammary vessels	3	0
Trachea	1	0
Total	158	11 (7%)

* Assumed from presence of hemopneumothorax.

also sustained an abdominal wound and died of peritonitis one week after admission. One patient died from cardiac arrest occurring during thoracotomy for continued blood loss. A perforating wound of the mid-zone of the lung was found at autopsy. There were two deaths from unrelieved tension pneumothorax. In one instance this complication was bilateral but treatment was directed to only one side. The other patient lived for 25 minutes in the accident room before expiring of acute anoxia. Pneumothorax had not been recognized and since there was evidence of severe external blood loss, treatment was being directed toward replacement of blood volume.

There were 14 instances of wounds of the heart and five of these patients died. In three of the five the diagnosis of penetration of a cardiac chamber was not made prior to death. One of these survived only 5 minutes in the accident room. Of the other 2 patients who expired, one was treated by immediate thoracotomy with repair of the laceration, and the other received a single pericardial aspiration. Of eleven patients with cardiac injuries in whom the diagnosis was made and appropriate therapy instituted, only 2 died, a mortality of 19 per cent; but all of the patients died in whom the diagnosis of cardiac injury was not made. There were two instances of perforating wounds of the great vessels, one involving the left innominate vein and one the intrapericardial portion of the ascending aorta. Both patients died. In neither was the correct diagnosis made prior to death. Three cases were admitted with laceration of major vessels in the chest wall. In two the internal mammary artery was injured and in one an intercostal vein. All were subjected to thoracotomy because of persistent bleeding and survived.

TABLE III

Penetrating Injury of Thorax—Associated Injuries

	Cases	Deaths
No associated injury	119	8 (7%)
Associated injury	39	3 (8%)
Head	1	0
Extremities	10	0
Abdomen	22	2 (9%)
Spinal cord	2	1 (50%)
Neck	6	1 (17%)

TABLE IV

Non-Penetrating Injury of Thorax—Etiology

Etiology	Cases	Deaths
Vehicular accidents	80	26 (33%)
Falls	20	4 (20%)
Fights	6	0
Other	1	0
Total	107	30 (28%)

There was one patient with a perforation of the intrathoracic trachea. This wound was repaired and he survived.

ASSOCIATED INJURIES

Among 119 patients with penetrating injuries of the thorax alone, 7 died, a mortality of 7 per cent (Table III). Only 39 patients had wounds outside the thorax. Of these, 3 died, a mortality of 8 per cent. There were 22 instances of abdominal penetration. No distinction is made here between separate wounds of thorax and abdomen and single wounds traversing both the abdominal and thoracic cavities. Two patients with abdominal penetration expired. Of 6 patients with wounds in the neck, in addition to a thoracic wound, one died. In ten cases there were one or more wounds of the extremities in addition to the thoracic wound and none of these patients died. Thus, there was no significant difference in the mortality of patients sustaining thoracic injury alone and those with wounds of other areas of the body as well. Of three patients with multiple wounds who died, the fatal injury was thoracic in two. One of these had a laceration of the heart and the other sustained a wound of the left innominate vein.

NON-PENETRATING INJURIES

There were 107 patients with non-penetrating injury to the chest, thirty of whom died; a mortality of 28 per cent (Table IV). This number does not include all patients with rib fractures since many of these are treated as out-patients.

TABLE V

Non-Penetrating Injury of Thorax—Age

Age	Patients	Deaths
0–1	2	1 (50%)
1–9	2	0
10–19	2	1 (50%)
20–29	14	7 (50%)
30–39	20	6 (30%)
40–49	20	2 (10%)
50–59	20	3 (15%)
60–69	18	5 (28%)
70–79	4	2 (50%)
80–89	4	2 (50%)
90–99	1	1 (100%)

TABLE VI

Non-Penetrating Injury of Thorax

Injury	Cases	Deaths
Fractured ribs	100	26 (26%)
Unilateral	87	20 (23%)
Bilateral	13	6 (50%)
Fractured sternum	5	3 (60%)
Laceration of aorta	2	2 (100%)
Laceration of esophagus	1	1 (100%)
Laceration of diaphragm	1	0
Contusion of heart	1	1 (100%)

Thus, in all the 107 patients injury was sufficiently serious to warrant hospitalization. Eighty patients were injured in motor vehicle accidents and 26 died. No distinction has been made in this analysis between injuries incurred from auto-pedestrian, train-auto or auto accidents, although this may be an important factor in survival. Twenty patients had been injured in falls and four of them died. Three of the four patients in this category who died were 77, 82 and 90 years of age respectively. Six persons had been involved in fights and one man was struck by a falling pipe. None of them died.

EFFECT OF SEX AND AGE ON SURVIVAL

Age did not significantly affect results in the treatment of penetrating injuries, but was an important factor in non-penetrating wounds (Table V). For instance, the youngest patients were two infants less than a year in age, while the oldest patient was a man known to be in excess of 90 years of age. Nine of 20 patients below the age of 30 failed to survive non-penetrating injury and 5 of 9 patients above the age of 70 also died. In contrast, only 20 per cent or 16 of 78 patients between the ages of 30 and 70 succumbed.

TABLE VII

Non-Penetrating Injury of Thorax—Associated injuries

	Cases	Deaths
No associated injury	49	6 (12%)
Associated injury	58	24 (42%)
Head	17	15 (88%)
Abdomen	14	6 (42%)
Extremities	43	15 (35%)
Spinal cord	2	2 (100%)

In all types of chest injury, men were more often involved than women in a ratio of 3:1.

EXTENT OF THORACIC INJURIES

In this group of patients as in those patients with penetrating injuries, the extent of injury was not fully known unless operation or autopsy was performed (Table VI). Since almost all (100 of 107) of these patients had a rib fracture, the significance of this injury is difficult to assess. It is evident that in patients with bilateral rib fractures and those with no rib fractures the mortality rates were somewhat greater than that for the group as a whole, whereas in patients with unilateral rib fractures the mortality rate was slightly less than that of the entire group. The apparent paradox of a higher mortality in patients without rib fractures is explained by the fact that in most instances these patients were children with pliable parietes in whom severe intrathoracic injury was possible without the occurrence of fractured ribs. Three of 5 patients with fractures of the sternum died. One of these had a laceration of the ascending aorta and the others had extensive bilateral rib fractures in addition to fracture of the sternum. Hemopneumothorax occurred in 61 of the 107 patients and in 22 of the 30 patients who died. The presence of air or blood in the pleural space was not thought to be the cause of death in any of these cases. There were two instances of laceration of the aorta and one of laceration of the esophagus; all of these patients died. In one case of laceration of the diaphragm repair was successfully accomplished. Myocardial contusion occurred once but was recognized only at autopsy. There were no cases of tracheal or bronchial injury recognized in this series, although we have subsequently treated two patients with these injuries. Similarly, no patients with lacerations of the heart survived to reach the hospital.

EFFECT OF ASSOCIATED INJURIES

In contrast to patients with penetrating injuries, damage to structures outside the thorax was accompanied by a pronounced increase in mortality in those with non-penetrating injuries (Table VII). Thus, among 49 patients with no extrathoracic injury, 6 died, whereas 24 of 58 patients with associated injuries succumbed. Seventeen persons had both thoracic and cerebral injury and only 2 or 12 per cent survived. Fourteen patients had both chest and abdominal injuries and 6 of these died, a mortality of 43 per cent. Of 43 patients having both chest and musculoskeletal injuries 15 died, a 35 per cent mortality. Two patients with spinal cord transection and concomitant chest injury failed to survive. Many of the patients had injury to more than one extrathoracic region. For instance, some had injury of brain, chest and abdomen. Others may have had four major body areas traumatized. Therefore, it is difficult to determine the effect on survival of specific injuries outside of the thorax. Where only chest injury and long bone fractures were present together, the mortality rate was only 16 per cent which is not significantly different from that of chest injury alone.

DISCUSSION

Historically, penetrating wounds of the thorax have carried a high mortality irrespective of their being a result of combat injury or incurred in civilian life. Much has been done, however, to improve the results of treatment in recent years by better understanding of the pathologic physiology of chest injury and by adoption of therapeutic measures designed to correct physiologic alterations. In this series the objectives in the management of patients with injuries of the chest were as follows: (1) to establish a patent air-way, (2) to restore circulating blood volume, (3) to secure pulmonary expansion by evacuation of blood and air from the pleural space, (4) to relieve cardiac tamponade by pericardiocentesis, (5) to stabilize the chest wall, (6) to control persistent hemorrhage and repair injury to mediastinal structures.

An attempt was made to apply these principles in the treatment of all patients in this series. If one assumes, then, that therapy was correct, there are two factors which appear to influence survival following penetrating thoracic injuries. These are the type of intrathoracic injury incurred and the rapidity and accuracy with which the diagnosis is made. Thus, of 11 fatalities among 158 patients with penetrating wounds, seven were due to wounds of the heart and great vessels. In one of the four instances where death occurred without injury to vascular structures, there was an associated perforation of an intra-abdominal viscus and death was the result of peritonitis.

Although the seriousness of cardiovascular injuries is evident from this study, it is also clear that a failure to recognize the existence of these lesions prevented their early and perhaps successful treatment. The same is true for non-vascular injuries such as tension pneumothorax and hemothorax. In fact, an accurate diagnosis was made on only four of the eleven fatal cases in the group of 158 patients.

While injury to other parts of the body may be a significant factor affecting survival of patients with penetrating injuries, this was not the case in this series. Thus, only three patients who had wounds of an extrathoracic site died and in two instances death was due to the chest injury rather than to the associated injury. Aside from a fatality resulting from peritonitis there were no deaths due to infection, pneumonia, pulmonary embolism or myocardial disease. This can be explained to some degree by the fact that the majority of these patients were young and previously healthy adults.

In analyzing the causes of death among patients with non-penetrating injuries of the chest certain facts are readily apparent. In the first place, the mortality of non-penetrating injuries is significantly higher than that for penetrating injuries. This was in spite of the fact that treatment was based upon the principles outlined above. This experience suggests that these principles of treatment may be based on inadequate knowledge of functional alterations after non-penetrating injury. Attention has long been focused on changes in intrapleural dynamics. Studies have recently been initiated in our laboratory to measure gas diffusion, lung-thorax compliance, air flow resistance and effective lung size after non-penetrating injury.

Unlike the experience with penetrating injuries, in these cases diagnosis was usually established promptly and an accurate assessment made of the extent of injury. Thus failure to make the correct diagnosis at the time of admission to the hospital was less important as a factor affecting survival in this group. Nor were injuries to the heart and great vessels a major problem since these injuries accounted for only three of thirty deaths occurring in the group.

Two factors which appear to be closely related to survival after a non-penetrating injury of the chest are the age of the patient and the type and extent of associated injuries. The high mortality observed in this series in the very young and very old patients supports the observations of Kemmerer and Reemtsma which were based upon a review of persons dying of traffic accidents and coming to autopsy in the coroners office in New Orleans (4). In their study, over half of the patients sustaining fatal injury to the chest were below the age of 20 or over the age of 65. This evidence together with that presented here suggests that patients in the middle years of life not only are more likely to reach the hospital alive but that once in the hospital, their response to treatment is better than that of the young or the old. The high mortality at the extremes of age suggests that modifications of therapy are perhaps indicated in order to provide for the physiologic peculiarities of patients in these age groups. This is particularly true in the treatment of the aged in view of the frequency of chronic pulmonary disease in these patients.

The presence of associated injuries clearly affects the mortality of non-penetrating trauma to the chest. The most serious associated injury is trauma to the head. On the basis of this study it appears that the damaging effects of head and chest injury are complementary. Thus, not only are mechanical factors present which contribute to alveolar hypoventilation but the compensatory mechanisms which might protect the patient from hypoventilation, such as cough reflex and sensitivity of the respiratory center to changes in blood gas composition, are less effective or are eliminated altogether. Although the correct diagnosis of simultaneous thoracic and cerebral injury was usually made, there may not have been a sufficient awareness of the combined effect of these injuries. Thus, the more frequent use of tracheostomy and the maintenance of adequate alveolar ventilation by means of mechanical respirators would undoubtedly have improved the survival.

SUMMARY

Two hundred and sixty-five patients with chest injury were treated on the Tulane Surgical Service of Charity Hospital from 1953 to 1958. The mortality for the entire group was 15 per cent. The mortality for penetrating injuries was 7 per cent and for non-penetrating injuries, 28 per cent. Factors which appear to influence survival in patients with penetrating injuries are the presence of wounds of the heart and great vessels and extent to which the correct assessment of injury is made. In the group of non-penetrating injuries the age of the patient and the presence of associated injuries are the factors of major importance. Thus, the mortality was highest in the young and old, and with associated injury, particularly cerebral trauma.

Awareness of the frequency of cardiovascular injury following penetrating wounds of the chest, modifications of the management of injuries in the young and old, and an increased awareness of the complementary effects of combined thoracic and cerebral injury should lead to improvement in survival.

REFERENCES

1. Avery, E. E., Mörch, E. T. and Benson, D. W. Critically crushed chests. J. Thoracic Surg., **32:** 291–311, 1956.
2. Bickford, B. J. and Grant, A. F. Surgical management of the "stove in" chest injury. Ann. Roy. Coll. of Surgeons of England, **19:** 371–382, 1956.
3. Culiner, M. D., Roe, B. B. and Grimes, O. F. The early elective surgical approach to the treatment of traumatic hemothorax. J. Thoracic Surg., **38:** 780–793, 1959.
4. Kemmerer, W., Eckert, W. G., Gathright, J. B., Reemtsma, K., and Creech, O. Jr. Patterns of Thoracic Injuries in Fatal Traffic Accidents. J. Trauma, **1:** 595–599, 1961.
5. Taylor, M. T. and Berman, E. J. Gunshot wounds of the chest in civilian practice. J.A.M.A., **173:** 1585–1586, 1960.

GIANT CELL TUMOR OF THE PATELLA ASSOCIATED WITH TRAUMA

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The pathogenesis of giant cell tumor is unknown. Geschickter and Kopland state that the tumor develops as a result of trauma with injury to the periosteal blood vessels. Then, overstimulation of osteoclastic activity ensues and revascularization occurs. Trauma has been reported in most cases of patellar giant cell tumor, but this bone is subjected to frequent injury (9). Some advance the theory that the tumors arise from connective tissue in the marrow (8). Others state that it is not a neoplasm but a low grade infectious response (10). There are those who feel that it arises from cancellous tissue of the long bones of the body (2).

Giant cell tumors of the bone occur mainly in the lower femur, upper tibia and lower radius. There have been twenty-eight cases of giant cell tumors of the patella reported. The last two in 1957 by Kelikian and Clayton were in young females. The average age was twenty-eight and one-half years. It was slightly more prevalent in females. The most popular treatment was excision of the patella. Six cases were curetted, two of which recurred; one partially excised; and three had extremity amputations (5).

CASE REPORT

N. J. L., 450594. Twenty-four year old white female.

The patient fell on her knee four years ago and experienced severe pain, but was able to bear weight. She first sought medical attention for her left knee in February 1960. She complained of pain and swelling of a "rheumatoid nature," the symptoms of which were increased in proportion to her activity. Examination revealed moderate left thigh atrophy, slight effusion of the knee, full range of passive motion but insecurity at the extreme of flexion on deep knee bending. There was no evidence of ligamentous damage or internal knee derangement. On palpation the patella was obviously deformed in a "pancake" pattern over the partially flexed knee. It was not tender to manipulation. X-rays were taken and a radiologist's report of enchondroma of the left patella was received.

The hematocrit was 43% and the leukocyte count 7,000 per cc. The differential was normal and the VDRL negative. The urinalysis was normal and an occasional urate crystal was reported. A miniature chest film showed no significant findings.

On February 19, 1960, a patellectomy through a transverse incision was done.

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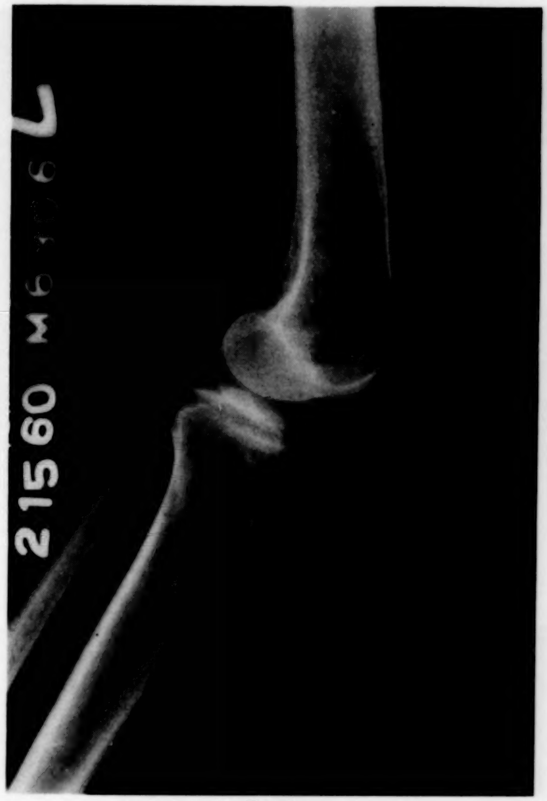

FIG. 1

FIGS. 1 AND 2. Left knee. The lesion is shown expanding and thinning out the cortex. Multiple cystic structures are scattered throughout the patella with no periosteal reaction.

The tendon was repaired using a V-plasty inversion as described by Schorbe and Dobson (12). The patella measured 5 cm. in diameter and 1.5 cm. in thickness. Inspection of the joint showed a superficial erosion of the cartilage of the medial femoral condyle measuring 2 cm. in diameter. There were no loose bodies in the joint space. A postoperative cylinder cast was applied with the knee in fifteen degrees of flexion. The patient was discharged four days after operation and was ambulating on crutches with little discomfort.

On pathological examination, the inner concave surface of the patella was covered by smooth glistening cartilage within which there were a number of irregular erosions. The erosions were superficial and linear in outline. The longest measured 1.5 cm. in length.

Sectioning showed the bony layer to be thinned out and represented by a calcified shell 1.5 mm. in thickness. Within this shell was spongy, pale-brown tissue which contained no calcified areas. A few collections of small blood sinuses

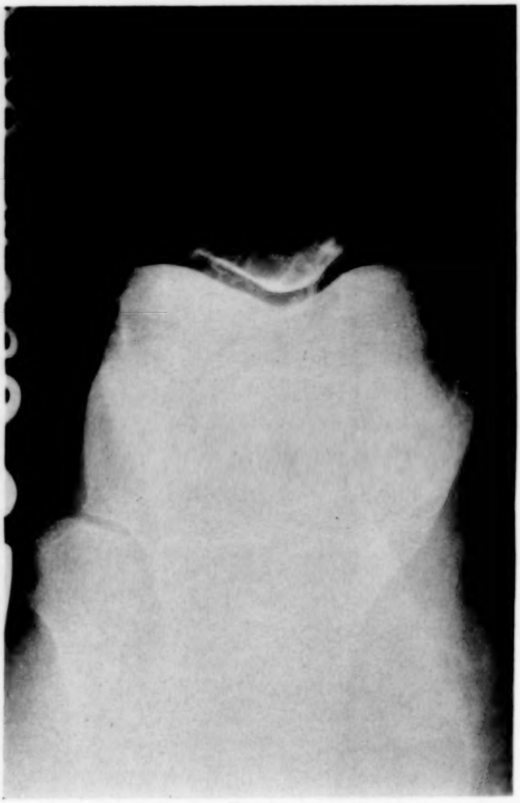

FIG. 2

were seen enclosed in hemorrhagic tissue. The tissue was completely enclosed by the calcified shell. No break-through of tumor was seen.

The section also showed a moderate number of giant cells containing irregularly distributed nuclei, rounded and vesicular. The stomal cells were loosely packed and nuclei were similar to the giant cells with little mitotic activity. The surrounding bone was extensively eroded. The vascular stroma was highly active. A grade I giant cell tumor of the patella was assigned because microscopic appearance showed insignificant atypism of the stromal cells.

Grossly the tumor was thought to be malignant. A consultation slide was sent to a surgical pathologist who confirmed the diagnosis but agreed that patellectomy should result in a cure. He also suggested that whenever there is a giant cell tumor unusual in its location or in histology, hyperparathyroidism should be kept in mind. The giant cell tumors that he regarded as malignant and which had run a malignant course evidenced considerably more manifestly malignant cells (3).

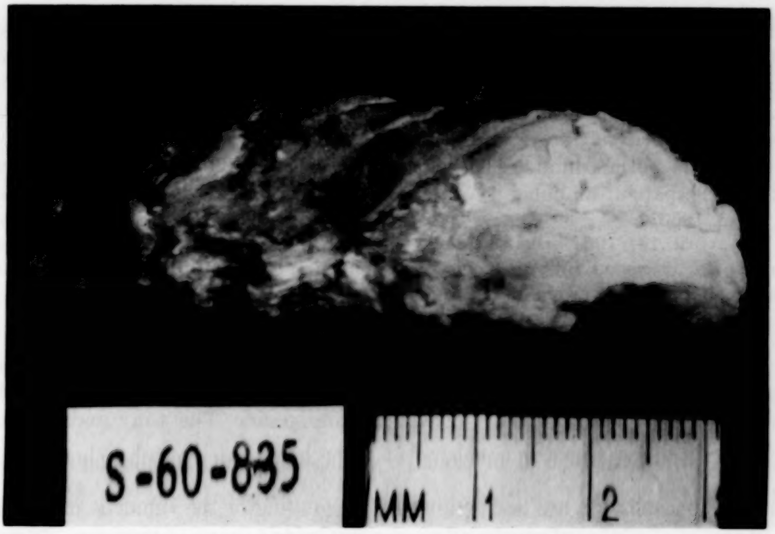

FIG. 3. The gross specimen

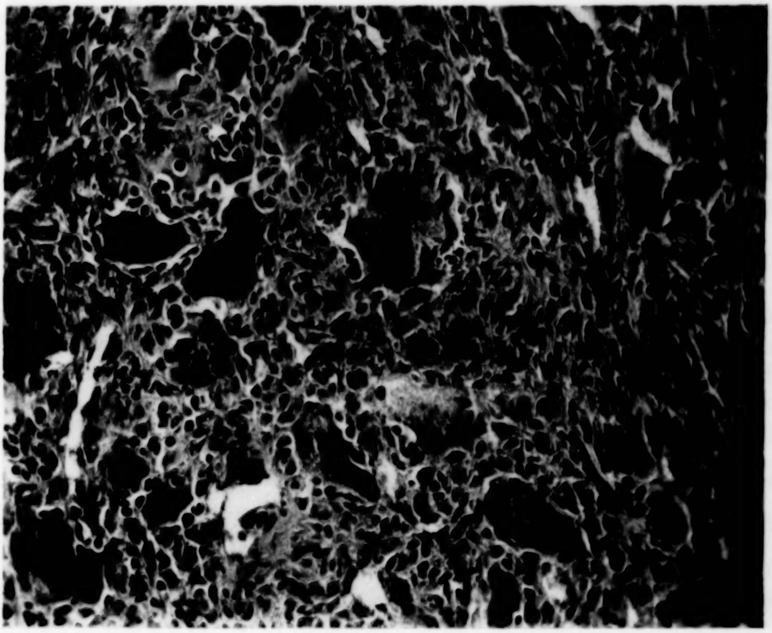

FIG. 4. Microscopic. Giant cells are scattered throughout the stroma

On March 29, 1960, the patient re-entered the hospital for an unrelated illness. The question of hyperparathyroidism in association with giant cell tumor suggested by the consultant was investigated. There was no clinical evidence of hyperparathyroidism. The Sulkowitch's test showed a 3+ precipitate. The blood calcium was 4.7 mEq/L and phosphorous 1.9 mEq/L which were within normal limits. The hematocrit was 32% and the VDRL was negative. The patient ambulated well during her hospital stay and was discharged April 2, 1960.

On April 14, 1961, the patient was interviewed and examined. The final follow-up indicated full recovery from the operation with normal stability of the knee and a full range of motion. No recurrence of the tumor was evident.

DISCUSSION

The tumor must be differentiated from advanced hyperparathyroidism, epulis, nonosteogenic fibroma and benign chondromyxoid fibroma of the bone. Neither laboratory nor x-ray studies are specific. The x-ray may be confused with fibrosarcoma or myeloma (4). The blood calcium, phosphorous and alkaline phosphatase are not deranged. The grading of the tumor is important and acts as a guide to therapy and prognosis. Grade I shows insignificant changes in stromal cells. Grade II shows moderate change and Grade III pronounced atypism (7). A complete patellectomy is recommended.

X-ray treatment is not advised. Post-irradiation sarcoma may occur and Jaffe states "that this may develop is no longer open to question and occurrences are probably not even rare" (4). Others feel that irradiation is superior to surgery and believe it is the treatment of choice in inaccessible areas such as the vertebral column (11). The chance of the tumor to infiltrate the knee joint is greater with pathological fractures. This, however, is not necessarily evidence of a malignant degeneration (5).

SUMMARY

A giant cell tumor of the patella is reported. The total number reported is now 29. There is no evidence that trauma was either an etiological factor or an aggravation of a pre-existing disease. It seems that hindsight usually produces a history of injury which gains in magnitude in the patient's mind as the lesion progresses.

BIBLIOGRAPHY

1. Chatterjee, S. N. Case report: Osteoclastoma of Patella. Brit. J. Radiol., **XII:** pp. 316–317, May 1939.
2. Coley, B. L. Neoplasms of the bone and related conditions, their etiology, pathogenesis, diagnosis, and treatment. pp. 162–205, New York, N. Y., Hoeber, 1949.
3. Dahlin, D. C. Mayo Clinic, Rochester, Minnesota. Personal communication.
4. Jaffe, H. L. Tumor and tumerous conditions of bones and joints. pp. 18–43, Philadelphia, Lea and Febiger, 1958.
5. Kelikian, H. and Clayton, I. Giant cell tumor of the patella. J. Bone Surg. Am. Vol. **39-A** (2) 414–420, April 1957.

6. LANTZOUNIS, L. A. Giant cell tumor of the patella treated by resection. New York State J. Med., **47:** 1018–1020, May 1947.

7. LICHTENSTEIN, L. Bone tumors. 2nd. Ed. pp. 119–145. St. Louis, Mosby, 1959.

8. MULLIGAN, R. M. Syllabus of Human Neoplasms, Ch. 2, pp. 50–53. Philadelphia, Lea and Febiger, 1951.

9. ROEMER, F. J. Benign giant cell tumor of the patella—Case report. Am. J. Surg., **67:** 563–566, March 1945.

10. SHANDS, A. Handbook of orthopedic surgery, 5th Ed. pp. 346–374. St. Louis, Mosby, 1957.

11. SHORVON, L. M. Giant cell tumors (Osteoclastomata) with report of a case in the patella. Brit. J. Radiol., **19:** 474–476, Nov. 1946.

12. SHORBE, H. B. AND DOBSON, C. H. Patellectomy; repair of extensor mechanism. J. Bone Surg. Am. Vol. **40-A6**, 1281–1284, Dec. 1958.

TRAUMA NEWS

Edited by
JAMES K. STACK, M.D.

In the August 12, 1961, Vol. 177, No. 6 issue of the J. A. M. A., pps. 31 to 443, is a compilation of the Council on Medical Education and Hospitals of "Continuing Education Courses for Physicians." This valuable annual effort is the 7th of its kind, the first being published in 1955. The objective, as stated by Dr. C. H. Wm. Ruhe of the A.M.A. staff, is to make an adequate list of continuing educational opportunities available to all practicing physicians so that they may assess their educational needs and then participate in suitable programs. In this way, their reading and practical experience will be enhanced. The purpose is to augment and modify an adequate initial medical education.

As this correspondent reviews this compilation, there is noted the absence of a category of "Trauma" in the Table of Contents. Under "Fractures," eight courses are available. Under "Orthopaedic Surgery", there are course titles which surely include traumatic lesions. Under "Physical Medicine and Rehabilitation," the subject of trauma is touched upon in several courses as it is under the heading of "Surgery."

Has it not been shown that trauma crosses all fields of surgery, that the morbidity and mortality of accidents is increasing annually in this country, and that there has been a most encouraging response from the medical profession to well-organized, postgraduate courses in the surgery of trauma? If you, the reader, agree that the field of the surgery of trauma is a fertile one for the continuing education of physicians, perhaps a note to Dr. Ruhe will bring this to the attention of the Council on Medical Education in Hospitals.

* * *

Did you know that 504 articles on trauma were published in the English literature from October, 1959 to November, 1960? A worthwhile review of these has been published by Dr. H. S. Miller of the Trauma Research Unit, Dept. of Surgery, Faculty of Medicine, University of British Columbia, Canada. The Director of this unit is Dr. Frank P. Patterson, a member of the Committee on Trauma of the American College of Surgeons. This excellent work is divided into paragraphs on body systems and brief resumes are given of those articles considered the most significant. The work was supported by the Canadian Defense Research Board, and is published in the Medical Services Journal, Vol. xvii, No. 3, pps. 148 to 178, March, 1961, The Veterans Affairs Building, Ottawa, Canada. This review is a must for the library of all those interested in the surgery of trauma.

EDITORIAL

The Walking Cast

The walking cast is not new. It was described by Krause in an article in German, published in 1891. However, to our own personal knowledge, it did not exist, at least we never saw one, until World War I. At that time, we found the boys were going out anyhow and, because crutches hindered the use of hands for other things, were walking on their casts, and, because the grass was usually wet in England, the casts were wearing out rapidly. We counteracted this by using an exceptionally heavy cast, even going to the extent of getting a leather boot to put over the plaster, thus legalizing the whole idea. The leather boot was rather like the Burberry coat which protected other parts of the body from the wet grass. These casts, of course, were all well padded. The permission to do this walking was given when it was quite evident that no matter how much movement or pressure was put on, no real harm would come to the individual.

Most were not recent fractures, or even fractures at all, but other conditions requiring ankle casts. However, it was not until Boehler's work at about the time of World War I, but known to us only much later, that the walking cast as we know it today really was developed. Our understanding is that Boehler first used the skin cast, which was something quite horrible when we first heard of it. But after one saw Boehler use his skin cast (our training had been plenty of padding and over-correction) one realized it could be done and it was done. Boehler used the skin cast, we understand, not as a stunt but because there was little or no cotton wadding on their side of the line in World War I. The net result of this was the ankle fracture, for instance, which, in the heavily padded cast, had usually been put up in marked supination, could, in a skin cast, be put up, squared off and straight, and fragments maintained in position. It was only a step from this to the addition of the walking iron.

The skin cast, as Boehler developed it, was really a skin cast and was well molded around the malleoli and well fitted to the leg up to the tibial condyle and head of the fibula. We do honestly believe that with a properly applied skin cast and iron rather than a rubber heel, most of the weight is taken up above the ankle. This, of course, would not be true in a person with no flare to his calf. But having worn one myself, I am convinced that the bulk of the weight can be taken out of the ankle itself by following Boehler's directions. However, it wasn't long until the housewife began to complain about the damage to the floors and rugs that the walking iron was creating and anyhow, it was easier to slip on a piece of rubber tire. Later the rubber heels were pushed by the salesmen.

One other thing not often appreciated was that the iron or heel raised the foot up and caused the leg to be too long on that side. Thus there was a tendency to rotate the foot of the longer leg during walking. This could be overcome if a small piece of wood, about one inch thick, was applied to the other shoe like a skate and thereby level the person up, as it were. This was carried out by us for some time and worked very well, but we rarely saw anyone else use this leveling idea and we saw many patients twisting as they walked.

Nevertheless during all this time, the difficulties of getting the cast off were considerable; even with good tools it was not easy, and everybody did not have good tools. (The best way to remove a skin cast safely is to put the patient in a tub of water and soak it off.) In addition to that, many, many people could not get it into their heads that a skin cast was safe. They felt that some padding must be used, and the minute any padding or even a stockinette is put on, the cast is no longer a skin cast, it is simply a sleeve around the ankle and the weight is carried on the bottom of the foot. The more the padding, the less the support and the greater the rotation.

Then came the electric cast cutter which, of course, ruined the whole situation as far as the skin cast was concerned. The skin cast simply has fallen into disrepute completely because one dare not have a patient in one that might be attacked by some interne with an electric cast cutter. Consequently, we ourselves rarely use the skin cast any more.

There are other factors, of course, which caused the walking cast to fall into disrepute. It was over done; it was used improperly, used in ankles in which it should not have been used, with the net result that traumatic arthritis developed in many cases where it might have been avoided had no walking cast been used. It was used in leg fractures and as we pointed out, there was a tendency to rotate; torsion forces were applied to the fracture, the more the padding, the greater the rotation. Consequently non-union was sometimes promoted. However, there was good in the walking cast. Before we started using it we saw a great many more cases of painful osteoporosis of the foot than we have seen since.

We think that, nevertheless, the real cause of the walking cast falling into disrepute was the use of padding, which was used first because of fear of the skin cast, but later became necessary because of the electrical gadgets we now have. In fractures of the foot and fractures of the ankle in which there is still a good mortise, a walking cast can be used quite successfully, even with padding.

RALPH G. CAROTHERS, M.D.

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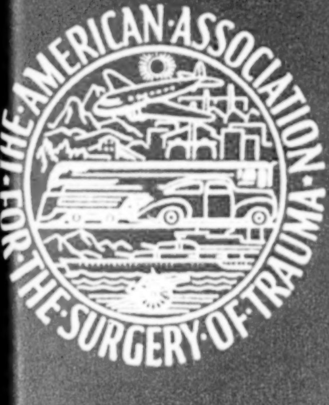

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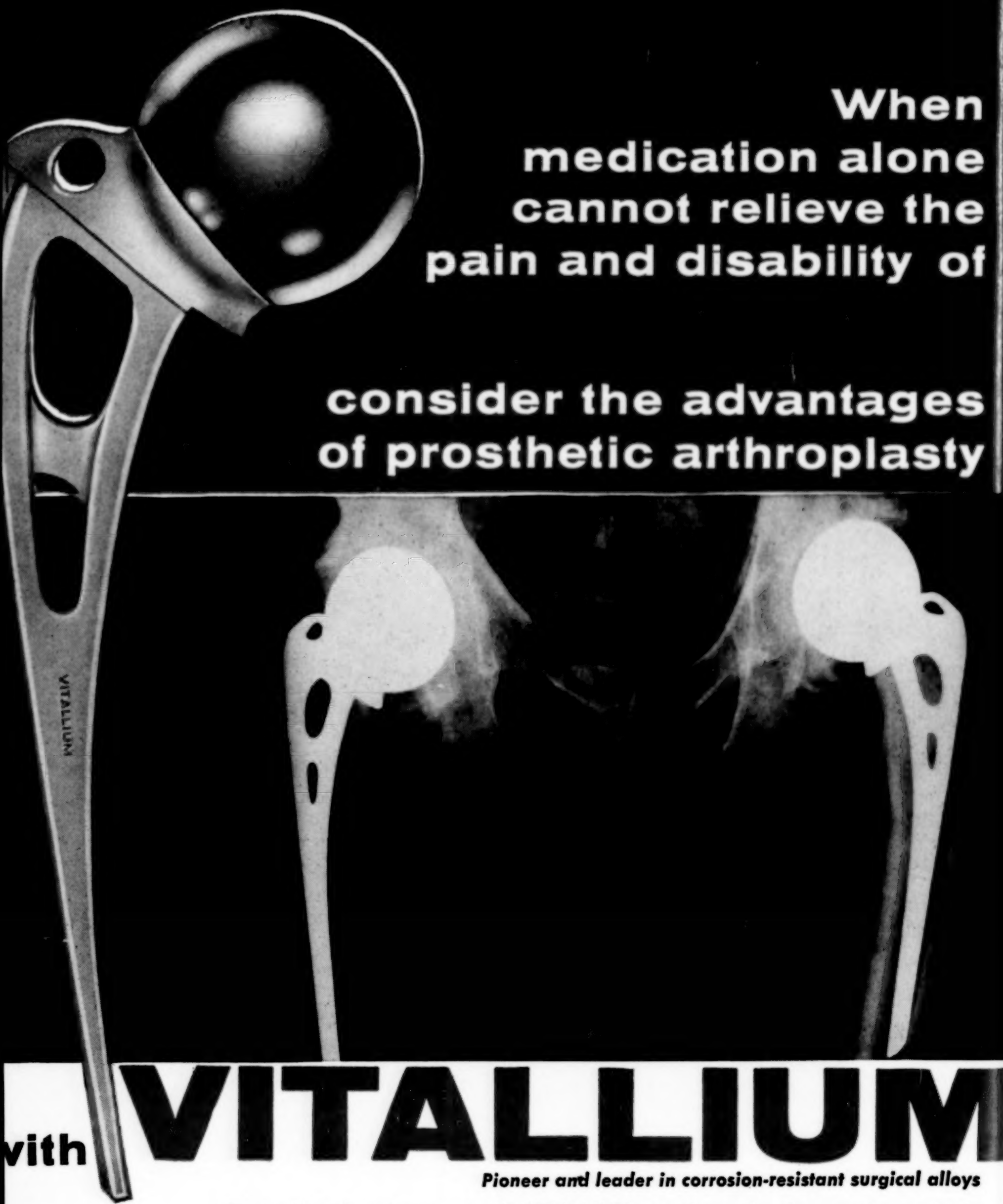

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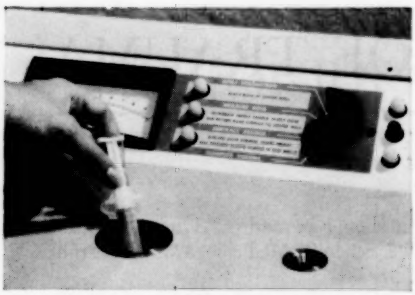

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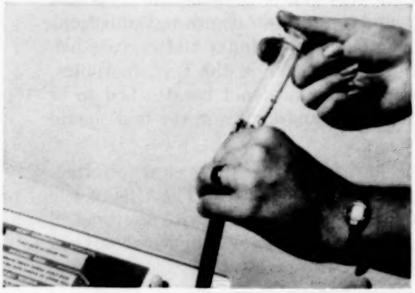

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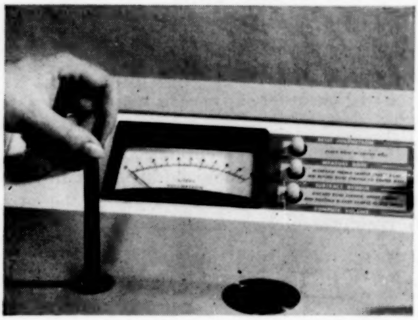

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